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Three Essays on Price Volatility and Trading Volume in Financial Markets.

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Three Essays on Price Volatility and Trading Volume in Financial Markets

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ABSTRACT

The objective of this dissertation is to examine the stock price volatility-volume relationship. The dissertation begins with an estimation of the time deformation market model in which stock contemporaneous trading volume is utilized as a proxy for the rate of information arrival. This local time market model is economically appealing because it is capable of explaining the observed heteroskedasticity and leptokurtosis in daily return data. With a sample of firms which have stock splits, it is shown that the inferences drawn from a modified event study which incorporates the local time market model are similar to those drawn from a typical event study which uses the simple OLS market model. In order words, a typical event study which employs daily stock return data and the OLS market model yields robust inferences in spite of the violation of the normality assumption in daily return data. The time deformation market model is also able to show that the increase in price volatility induced by stock splits is due to a structural change in the relationship between economic time and calendar time.

The impact of option introduction on the stock price volatility-volume relationship is investigated. The asymmetric price change-volume relationship is affected by

option trading because option trading is capable of reducing the short selling constraints. Although exactly how option trading can affect the asymmetry is a complex matter, the empirical findings do give mild support to the hypothesis that option trading can attenuate the asymmetric price change-volume relationship. Option trading also influences the local time market model. Empirical evidence is supportive of a structural shift in the model. These findings are consistent with the notion that information flows to both the stock and the options markets when option trading is viable. Also, one-day-lagged option volume is important in explaining the conditional return variance.

CHAPTER I

INTRODUCTION

Many theoretical models in finance are built on the premise that investors are homogeneous (for instance, the capital asset pricing model (CAPM)).[1] In other models, aggregate demand curves are perfectly elastic and supply curves are either perfectly elastic or perfectly inelastic (Ross (1987)). That is, securities are close substitutes for one another. In a world of no arbitrage, the quantity of securities traded has no relevance in the determination of the equilibrium price. The theoretical issues, coupled with the relative scarcity of volume data have left trading volume out of the mainstream of financial research. Nevertheless, the vast amount of trading activity in most financial markets seems to indicate heterogeneity among investors. Further, a growing body of empirical evidence regarding the price volatility-volume relationship indicates an increase in the significance of trading volume in financial research (Karpoff (1987)).[2]

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[1] The CAPM is due to Sharpe (1964), Linter (1965), and Mossin (1966).

[2] The term stock price volatility has been used very loosely in the literature. It can represent the square of price changes, the absolute value of price changes, the return variance, the residual return variance, etc. In this dissertation, Chapters III and V examine the conditional variance of return residuals while Chapter IV deals with

Research on the relation between price volatility and trading volume is important for at least three reasons. First, trading volume is important in understanding the distribution of speculative prices. In explaining the leptokurtosis of the empirical distribution of daily return data, Clark (1973) posits a subordinated stochastic process model in which the evolution of daily prices is subordinated to the flow of daily information measured by the number of transactions (proxied by total volume). Alternatively, Epps and Epps (1976) hypothesize that speculative prices follow a mixture of normal distributions, with trading volume as the mixing variable.

Second, a better understanding of the price volatility-volume relationship will shed light on the methodologies of event studies which incorporate trading volume. A number of researchers combine both volume and return data in event studies to draw additional inferences (see, e.g., Beaver (1968), Morse (1980,1981), Pincus (1983), Bamber (1986,1987), Lakonishok and Vermaelen (1986), Richardson, Sefcik, and Thompson (1986), Harris and Gurel (1986), Lamoureux and Poon (1987), and Lamoureux and Wansley (1987)). Trading volume reaction and its relation to information content around an event are frequently employed to draw additional inferences in a typical event study.

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return residuals.

Third, in the literature of market microstructure, trading volume is pivotal in modelling the structure of financial markets. For instance, trading volume is hypothesized to be inversely related to the relative bid-ask spread (e.g. Demsetz (1968), Benston and Hagerman (1974), and Stoll (1978)). Trading volume is also important in understanding how information is disseminated and in measuring the rate of information flow in financial markets (for instance, see Holthausen, Leftwich, and Mayers (1987) and Easely and O'Hara (1987) for the effect of large block transactions). Given that a stock has options listed on an organized exchange, e.g., Chicago Board Options Exchange (CBOE), the price volatility-volume relationship in related markets (stock and options) will provide new insights into the process by which information is revealed in financial markets.

The main objective of this dissertation which is composed of three essays is to contribute to the literature in price volatility and trading volume, particularly, in the above three areas. Lamoureux and Lastrapes (1988) show that daily trading volume, used as a proxy for economic time, can explain the observed heteroskedasticity in daily stock return data. The use of volume in proxying for economic time gives rise to an interesting experiment to examine the impact of stock splits on price behavior and trading activities, in light of the observation that splits induce significant increases in price volatility and raw trading volume (Ohlson and Penman (1985) and Lamoureux and Poon (1987)). Another goal of Essay I (Chapter III) is to modify a traditional event study on stock splits, in the presence of heteroskedasticity, with a re-definition of the notion of abnormal rate of return.

An asymmetry in the price change-volume relationship has been documented in several studies. In essence, the relationship is stronger for positive price changes than for negative price changes. Two propositions have been offered to explain the asymmetry. The first one is associated with some behavioral assumptions among different investors (Epps (1975)). The second explanation is related to the relatively higher costs in taking a short position than a long position in a stock (Jennings, Starks, and Fellingham (1981) and Karpoff (1989)). Since option trading (on the underlying stock) reduces the short selling constraints, the proposition that option trading is capable of attenuating the asymmetry is an important empirical question. Essay II (Chapter IV) is devoted to this issue.

The existence of the price volatility-volume relationship in the stock market arises mainly because of the presumption that information is being impounded in the prices through trading. Since the stock market and the options markets are inter-related, it is natural and logical to conjecture the relationship between stock price volatility and the aggregate trading volume in both markets. To date, no empirical research examines the price volatility-volume relationship in these related markets. This study is important if we wish to better comprehend the inter-relationship of the two markets. Accordingly, Essay III (Chapter V) is an empirical examination of the relationship between stock price volatility and trading volume in both markets.

CHAPTER II

REVIEW OF LITERATURE

Academic literature related to stock price volatility and trading volume usually arises from the following settings: the empirical distribution of daily return data, the relationship between information and volume, and market microstructure. These issues are not mutually exclusive.

1. Theory

The distribution of stock returns is always essential to theoretical and empirical research in finance. The first study of speculative price behavior dates back to 1900 by Bachelier. The central theme of both Bachelier (1900) and Osborne (1959) is that price changes from transaction to transaction are independent and identically distributed (iid). If transactions occur uniformly across some time interval (e.g., daily), then daily, weekly, or monthly price changes will be the sum of many independent variables over the interval. Then, price changes wili have a Gaussian distribution according to the central limit theory (CLT), provided that the common distribution from which price changes are drawn has a finite second moment. In this context, the first and second moment of the return distribution are the only arguments of a risk averse investor's utility function (Tobin (1958)). This normality assumption is crucial in the derivation of many theoretical models, e.g., the CAPM.

A large body of empirical evidence shows that daily stock return distributions exhibit leptokurtosis (see, for examples, Mandelbrot (1963) and Fama (1965)). Researchers then shift the attention to the explanation of the leptokurtosis. Mandelbrot (1963) and Fama (1965) hypothesize the stable Paretian distributions which are the only possible limiting distributions for the sums of iid random variables. The most important properties of the stable Paretian distributions are infinite variance (when the characteristic exponent is less than 2) and stability under addition. Empirical evidence of the stable Paretian hypothesis is however somewhat discouraging as Officer (1972) and Blattberg and Gonedes (1974) report violations of the stability property.

Other return generating models are posited to explain the observed leptokurtosis. For instance, in a mixture of normal distributions (Kon (1984)), returns are drawn from a set of normal distributions with different variances. One explanation of the mixture of normals is that daily returns on different days of the week are drawn from different common distributions, e.g., Monday's returns might be different form the rest of the week. Notwithstanding a good fit of return data, the mixture-of-distributions models lack economic appeal because we cannot identify (ex-ante) the number of distributions in the mixture and from which distribution a particular observation is drawn (ex-post).

Mandelbrot and Taylor (1967) and Clark (1973) propose a subordinated stochastic process model for daily returns to explain the leptokurtosis.[3] Traditionally, returns are presumed to evolve in a calendar time basis. However, in Clark's subordinated process, the underlying directing process is the rate of information flow measured by the total number of transactions which is proxied by daily trading volume. Subsequently, the distribution of daily returns is conditional on trading volume.

Other researchers employ the technique of autoregressive conditional heteroskedasticity (ARCH) introduced by Engle (1982) in stock return modelling (e.g, French, Schwert, and Stambaugh (1987)). In an ARCH model, the conditional variance depends on past variance(s); shocks to variance are persistent over time. This persistence is capable of explaining the observed heteroskedasticity. In spite of an apparently good fit to the data, no economic rationale is given.

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[3] Although Clark (1973) is frequently cited in the literature, Mandelbrot and Taylor (1967) are the first to suggest the subordinated stochastic process in which trading volume is the directing process to describe return data.

Recently, Lamoureux and Lastrapes (1988) propose the use of daily trading volume to explain the observed heteroskedasticity. In their model, stock prices evolve in economic time instead of calendar time. So the evolution of stock prices is faster on days when more economic time elapses. Economic time is assumed to be the information flow which in turn is proxied by daily trading volume. They demonstrate that the standardized volume adjusted returns tend to be normally distributed according to the CLT. They further hypothesize and show that the ARCH effect, which is employed to explain the heteroskedasticity, is indeed a proxy for time deformation. The concept of time deformation is the central theme of Chapter III because it is more economically appealing than other models that attempt to explain the leptokurtosis and it has profound implications on other issues such as event studies.

As Mandelbrot (1973) notes, Clark's model is one form of the mixtures of normal distributions, where daily price changes are drawn from a set of normal distributions that are characterized by different variances. Epps and Epps (1976) derive another form of mixture of distributions which yields similar empirical implications to those of Clark's (1973) model. In Epps and Epps' model, the disagreement among traders is positively related to the absolute change in prices. Since volume is also positively related to the degree of disagreement, the mixture of distributions arises.

Aside from the context of explaining the empirical distribution of daily returns, there are several models which also predict a positive relationship between price changes and volume, and further that this relationship is asymmetric with respect to positive and negative price changes. For instance, in Epps' (1975) model there are two groups of investors in the markets - the "bulls" who are more optimistic and respond only to positive information while the "bears" are pessimists and react only to negative information. Assuming information is disseminated simultaneously to all investors, Epps demonstrates that the market demand curve is steeper than the market supply curve. The implications that emerge are not only that price changes are related to transaction volume, but also that the relation between positive price change and volume is stronger than that between negative price change and volume.

Contrary to Epps' (1976) simultaneous information dissemination model, Copeland (1976,1977) constructs a sequential information arrival model in which information is received only by one trader at a time. Investors are either optimistic, pessimistic, or uninformed and uninformed traders do not infer the information from informed traders' transactions. Information arrival will cause an upward shift in each optimist's demand curve but a downward shift (by the same magnitude) in each pessimist's demand curve. When short selling is restricted, Copeland's model implies: (1)

a positive relationship between the absolute value of price changes and trading volume; and (2) volume is the greatest when traders are unanimous about the information.

Copeland's model is subject to three major criticisms, however. First, market prices do not reveal any information in his model. Second, the more investors agree upon the information, the greater the volume of trading. This contradicts Clark (1973), Epps (1975), and Epps and Epps (1975); and lacks intuitive appeal.[4] Finally, short sales are not allowed at all. In the real world, short selling of a stock is permitted, though usually at a higher cost than taking a long position.

In light of these criticisms, Jennings, Starks, and Fellingham (1981) modify Copeland's model by relaxing the short selling prohibition. In addition to allowing short selling by imposing a margin requirement, Jennings, Starks, and Fellingham formulate the market adjustment process (to information) through an equilibrium analysis where each investor (optimist, pessimist, and uninformed) maximizes the expected utility of terminal wealth under uncertainty. The major implication is the existence of an asymmetric price change-volume relation mainly due to the margin requirement on short selling.

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[4] Recently in an experimental study, Copeland and Friedman (1987) show that trading volume is significantly higher in a simultaneous information arrival setting than in a sequential information setting.

Most theoretical analyses treat information and therefore volume as exogenous and do not consider non-informational, e.g., liquidity trading. Tauchen and Pitts (1983) construct a model in which time-aggregated volume and price variability are conditional upon exogenous information flow. They thus derive a joint probability distribution of price variability and volume. Furthermore, they suggest, if trading volume follows a trend, then empirical results on the price volatility-volume relationship may be misleading when the trend is omitted.

The endogeneity assumption of volume is also shared in a dynamic asset pricing model developed by Huffman (1987). He argues that the stochastic processes governing asset prices are likely to affect other factors in the economy, e.g., volume and rates of return.

Pfleiderer (1982), in a rational expectations model similar to Grossman (1976) except for the crucial allowance for noisy trading (e.g., trading motivated by life-cycle considerations), demonstrates that volume is a declining function of the precision of information and that the correlation between price variability and volume can be used to detect private information. But the relationship between consensus and volume is not clear because Verrecchia (1981) and Karpoff (1986) claim that the relationship is extremely complex. In particular, Verrecchia shows that total consensus among investors is a necessary but not sufficient condition for no trading to occur, depending on investors' risk preferences.

In sum, trading volume has been utilized in many models to explain the empirical distribution of return data. Other theoretical models predict a positive relationship between price change and volume and relate it to information. The link between consensus and volume is ambiguous. Some models further imply an asymmetric relationship because of certain behavioral assumptions and/or short selling constraints.

2. Empirical Evidence

Empirical evidence is usually consistent with inferences drawn from theoretical models discussed in the previous section. Ying (1966) is among the first to report a significant relationship between price volatility and volume. His work is motivated by Granger and Morgenstern (1963) and Godfrey, Granger, and Morgenstern's (1964) failure to uncover the price volatility-volume relationship. However, Ying's study is easily criticized because he uses two incompatible series of data - daily Standard and Poor (S&P)'s 500 index and daily New York Stock Exchange (NYSE) volume. Unlike Ying, Crouch (1970) uses daily and hourly price and volume from the NYSE (1966-1968) and detects a positive correlation between the absolute values of price change and volume.

Then, in the 1970s, more research on this issue is stimulated by Clark (1973), Epps (1975), Epps and Epps (1976), and Copeland (1976,1977). Clark (1973) himself uses daily cotton futures price and volume data from 1945-1958. After grouping the data by the ranges of volume, he finds that the sample kurtosis of each group is significantly smaller than that of the ungrouped data; further, the group densities are closer to the Gaussian model. He also shows that the price volatility-volume relationship is nonlinear. Mandelbrot (1973) however argues that Clark's work is just a matter of curve fitting.

Clark's (1973) model also implies that stock price volatility is heteroskedastic in the sense that the variance depends on volume and that the conditional distribution (adjusted by volume) is log-normal. Testing of these two hypotheses is the main objective in Morgan's (1976) study. With the use of daily (4-day intervals) and monthly data, he documents the heteroskedasticity but fails to account for the leptokurtosis, especially for daily data.

Some studies extend Clark's model. Westerfield (1977) conducts an experiment similar to Clark's except that he utilizes daily individual stock return data from the NYSE. Westerfield concludes that actual stock price volatility is better described by a subordinated stochastic process model than a stationary asymmetric stable model. Upton and Shannon (1979) derive the asymptotic tendencies of a subordinated stochastic process and show that monthly stock return data are better described by the subordinated stochastic process than a stable Paretian distribution.

Karpoff (1988) hypothesizes that the price change-volume relationship (as distinct from the volatility-volume relationship) in equity markets stems from the fact that the cost of selling short is greater than that of taking a long position in a stock. He finds support for the proposition by showing there is no relationship between price change per se and volume in the futures markets where investors face symmetric costs of both positions.

Lamoureux and Lastrapes (1988), using an estimation procedure derived from the ARCH technique, document empirical results which are consistent with the time deformation return generating model. Out of 20 stocks in their sample, they show that 9 have normally distributed volume-adjusted returns. Without volume adjustment, the returns uniformly depart form normality. More significantly, they discover that the ARCH effect is actually proxying for the time deformation process. For the purposes of this dissertation, their results have the following implications: (1) the usual notion of (daily) abnormal rate of return must be re-defined; (2) standard event studies should be modified in the context of a time deformation market model; and (3) the availability of organized option trading may affect the process of time deformation since the economic clock is likely to involve trading activities in both stock and options markets.

With empirical results on 20 common stock transaction data from NYSE, Epps and Epps (1976) support the mixture of distributions hypothesis. Harris (1987), using 50 NYSE stocks' daily data, favors the mixture of distributions hypothesis. Further, he shows that price changes are heteroskedastic and volume is skewed because transaction return data can be described by a mixture of distributions.

Tauchen and Pitts (1983) show that daily data from the Treasury bill futures market are consistent with the mixture of distributions hypothesis. Further, they estimate the parameters of the joint distribution of the mean daily trading volume and the variance of the daily price changes by maximum likelihood and show that they are jointly determined by the average daily rate of new information flow to the market.[5] They also demonstrate a trend in trading volume and that the prices tend to be stabilized by an increase in the traders.

A causality test between price volatility and volume is conducted by Rogalski (1978). His data base consists of

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[5] Tauchen and Pitts' (1983) work implies that there might exist simultaneity bias in empirical studies which regress price volatility on volume and vice versa. When price volatility and volume are jointly determined by the rate of information flow as Tauchen and Pitts show, the parameters estimated from regressing price volatility on volume and vice versa might be biased.

monthly data of 10 common stocks and their associated warrants. With the use of an independence/causality test, he concludes that security price volatility and volume are dependent and that feedbacks occur in both directions.

Epps (1975) examines the asymmetric price change-volume relationship by studying the relation of the absolute value of positive and negative price change to volume on one day (in January) with 20 NYSE bonds. The empirical evidence lends support to the asymmetry hypothesis. Later, Epps (1977) attempts to prove that the asymmetry also exists in the stock market. Again, he utilizes one day data (also in January) of 20 NYSE stocks and obtains results consistent with his earlier work. Nonetheless, Epps' results are subject to a drawback - the possible biases from the data in January. Although the notion of the January effect is not well documented at that time, Hanna (1978) notices that January has the sharpest surge in prices. So, Hanna replicates Epps'(1975) study with one day data from May. Epps' results still hold. Epps' asymmetry hypothesis is further supported by Smirlock and Starks (1985). With a sample of transaction data for all NYSE stocks which have an earnings announcement during June 15 to August 21, 1981 and listed options, they find support for the asymmetry hypothesis. However, they notice that this holds only on the day when there is information arrival (i.e., earnings announcement). They therefore assert that the asymmetry is related to information arrival.

Unfortunately, Smirlock and Stark's sample selection criterion may create potential biases; option listing might be capable of attenuating the asymmetry as a result of reduction in short selling constraints (see Chapter IV).

Surprisingly, the options markets which are so closely related to the stock market have received scant attention in the literature. Chapter V is directed to fill in the gap.

3. Applications

The relation of volume to information and to price volatility has been integrated in typical event studies to draw additional inferences. Beaver (1968) originally analyzes the residual volume obtained from regressing the stock volume on the market (NYSE composite) volume around a specific earnings announcement. He detects a significant increase in the residual volume on the announcement day and concludes that the announcement has "information content." Beaver does not conjecture whether volume, along with price volatility, reflects a lack of consensus or disagreement among investors. He argues that both will be reflected. Of course, his conjectures are not inconsistent with the doubt cast on the link between investors' consensus/disagreement and volume by Verrecchia (1981) and Karpoff (1986) as discussed earlier.

There are several studies pursuant to Beaver (1968). Morse (1981) finds that higher trading volume is usually associated with serially correlated return residuals and argues that informed traders will trade on private information until the price fully reflects the information.

But volume and price volatility themselves may well be dependent on the magnitude of unexpected earnings and firm size, both in turn related to the information content of the earnings announcement. This conjecture is supported by Bamber (1986,1987) who confirms that both magnitude of unexpected earnings and firm size are related to the information content of annual earnings announcements. Also, the magnitude and duration of trading volume reaction around the announcement are found to be positively correlated with the absolute value of the unexpected earnings, but inversely correlated to firm size.

The price volatility-volume relationship is also applied in other research, e.g., dividend policy, stock split, and price pressure. Richardson, Sefcik, and Thompson (1986) examine the volume reaction to a change in dividend policy to test the hypothesis of dividend irrelevance. With a sample of firms announcing their first cash dividends, they document an increase in both trading volume and firm value around the announcement day. They further demonstrate that the volume increase is consistent with the signalling hypothesis and suggest that clientele adjustments are small. On the other hand, Lakonishok and Vermaelen (1986) investigate trading volume around ex-dividend days. Trading volume increases significantly around the ex-day, particularly for high yield, actively traded stocks, lending evidence to a tax-induced trading hypothesis.

Ohlson and Penman (1985) report that stock price volatility increases significantly subsequent to the ex-split day. Failing to find any successful explanations, they refer to this as an aberration. After finding no increase in split-adjusted weekly volume on the ex-split day, they then suggest that volume is of limited use in explaining the increase in volatility. However, Lamoureux and Poon (1987) delineate the scenario by showing that part of the increase in volatility comes from the disturbance term in the market model. In addition, they document a significant increase in daily raw trading volume after the ex-day and show that volume is related to the increase in volatility subsequent to the split in a context of a tax option model.[6] Their results imply that stock splits may affect the stochastic behavior of stock prices and trading process. These issues are examined in Chapter III. In another setting, both Harris and Gurel (1986) and Lamoureux and Wansley (1987) incorporate

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[6] The tax option model is originally developed by Constantinides (1984).

volume data with price behavior and support the price pressure effect on stocks placed on the S&P's 500 - a possibility also suggested by Lamoureux and Poon (1987) to explain the ex-split day price behavior.

Most of these empirical studies employ volume to strengthen or support their inferences drawn from examining the price pattern. As Karpoff (1987) mentions, no research has yet been conducted to examine how the price volatility-volume relationship can be utilized to construct a more valid test (e.g., the t-test in an event study). The t-test in a typical event study assumes a stationary return residual variance which is heteroskedastic in a local time market model. One goal of Chapter III is to modify a typical event study in the context of a local time market model.

Also, the effect of option trading on the price volatility-volume relationship has never been explored. The principal rationale is that information is likely to flow to both markets. Therefore, empirical studies of the relationship which ignore the impact of option trading are subject to possible bias. Chapters IV and V will center on these issues.

In conclusion, trading volume has been incorporated in both theoretical models and empirical studies to enhance our understanding of the microstructure and equilibrium (or disequilibrium) in capital markets. It is because trading volume is able to demonstrate how information is revealed in the market. Most equilibrium asset pricing models, e.g., the CAPM are reticent concerning trading volume. Unsurprisingly, inconsistent (with the implications from the CAPM) empirical evidence has been documented (e.g., Tinic and West (1986)). Trading volume might be an important factor in equilibrium asset pricing models (see Huffman (1987) in which transaction volume is incorporated in a dynamic equilibrium asset pricing model).

CHAPTER III

A TIME DEFORMATION MARKET MODEL AND EVENT STUDIES: THE CASE OF STOCK SPLITS

1. Introduction

Although empirical evidence overwhelmingly shows that daily stock return data violate the assumption of spherical disturbances, the ordinary least squares (OLS) market model is generally used and accepted in event study methodologies. Brown and Warner (1985) demonstrate that the non-normality of daily returns has little impact on event study methodologies. However, they show that the choice of variance estimator might affect both the specification and power of the tests in event studies. The first objective of this chapter is to modify a standard event study given a local time market model which is capable of explaining the heteroskedasticity observed in daily return data and examine how inferences might be affected when the simple OLS market model is otherwise used.

In a typical event study, to compute the statistical significance of the excess return on a day (e.g., an announcement day), the mean excess return of the portfolio is divided by the estimated standard deviation which is assumed to be stationary and obtained from some non-event period. However, in a time deformation market model, stock price evolves much faster on a day with more information flow (e.g., an announcement day) than on a day with less information flow. The common definition of abnormal (daily) return therefore should be re-examined. Moreover, the calendar time variance of the error term is not constant, hence, the t-statistic in an event study should be adjusted accordingly.

The second objective of this chapter is to investigate the impact of stock splits on the stochastic behavior of price and trading process in a context of time deformation. The increase in price volatility and trading volume due to the split might stem from a structural shift in the local time market model, i.e., there may be a change in the relationship between economic time and calendar time.

2. A Time Deformation Market Model and Stock Splits

A. A Time Deformation Market Model

Following Lamoureux and Lastrapes (1988), a local time market model can be specified as follows[7]

(3.1) $$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$

(3.2) $$\epsilon_{it} | V_{it} \sim N(0, h_{it})$$

(3.3) $$h_{it} = a_{i1} + c_{i1} V_{it}$$

The first equation is the mean return generating equation for stock i at time t (day t). R_{it} and R_{mt} are stock i's return and the market return respectively. α_i and β_i are the intercept term and the slope coefficient in the market model. The distribution of residual ϵ_{it} is conditional upon V_{it}, the raw daily trading volume; h_{it} is the conditional variance. V_{it} is assumed to be weakly exogenous (in the sense of Engle, Hendry, and Richard (1983)).

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[7] In their original model, Lamoureux and Lastrapes (1988) examine the total variance of daily stock returns. For the purpose of investigating the impact of time deformation on event studies which use the market model, we separate the market-related and idiosyncratic components of daily stock returns and assume the latter evolves in local time.

The model presumes that Z(t) (some measure of calendar time daily return) may be written as X[T(t)] where X(t), a Markov process, is the rate of return measured in local time with a finite variance σ^2 and T(t) is a positive stable stochastic process. Let T(t) represent the (firm specific) information flow to the market on a particular day. Of course, T(t) is not observable. Further, let n be the random number of "information arrivals" of that day (the independent intradaily increments of local time, T(t)). Then X[T(t)] itself is also a Markov process which is subordinated to X(t) using the operating time (or directing process) T(t) (Feller (1966)). If the market is informationally efficient, then $Z_{it} = \Sigma^n_{t=1} X(t)$ and the variance of $Var(Z(t)) = n\sigma^2$ because the the intradaily increments of Z(t) are independent, implying the heteroskedasticity of the conditional distribution of daily returns (as n varies daily). Moreover, we segregate the systematic component from the unsystematic component in R_{it} and assume the latter is time-deformed. That is, Z(t) represents the idiosyncratic component of daily return, ϵ_t. V_{it} is treated as an adequate though not perfect proxy for the firm specific information arrival rate, T(t). As a result, the standardized, or volume adjusted, residual $\epsilon_{it}/h_{it}^{1/2}$ is normally distributed according to the CLT (if n is sufficiently large).

B. The Impact on Event Studies

In a time deformation (or local time) market model, the reaction of stock price to an event in a local time market model might not be abnormal since there are more information arrivals (or local time elapsed) around the event period. Recall the rate of evolution of stock price is different on different days because the rate of information flow is faster on some days (e.g., the event period). Therefore comparing the (abnormal) rate of return on the event day to that on a non-event day may be analogous to comparing weekly returns to daily returns. We should use the standardized residual to adjust for different information arrival rate. Given that the daily conditional variance of the residuals is no longer stationary, the testing procedure for the significance of the portfolio's excess return must be re-defined.

A typical event study (e.g., Brown and Warner (1985)) that uses daily return data can be presented as follows. For each individual stock, the following OLS market model is estimated

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it} \tag{3.4}$$

We then obtain the excess return on day t as

$$e_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt} \tag{3.5}$$

To test the statistical significance of the excess return on an equally weighted portfolio (of N securities) on a particular day t, the following computations are performed

(3.6) $AR_t = 1/N \; \Sigma^{N}_{i=1} e_{it}$

(3.7) $AE = 1/T \; \Sigma^{T}_{t=1} AR_t$

(3.8) $\hat{S}(AE) = [\; \Sigma^{T}_{t=1} (AR_t - AE)/T-1 \;]^{1/2}$

where T is the estimation (non-event) period, AR_t the portfolio's average excess return on day t, AE the average excess return over T, and $\hat{S}(AE)$ the estimated standard deviation and assumed to be stationary over time (including the event period).

The test statistic for testing the significance of the excess return on the event day (for both the announcement day and the ex-split day) is

(3.9) $A_0 = AR_0/\hat{S}(AE) \sim t(T-1)$

A_0 follows a t-distribution with T-1 degree of freedom (d.f.). If A_0 is statistically significant, the abnormal excess return is then significantly different from zero, and it is inferred that the event has an impact on the value of the firms in question, and more generally, that the event has information content.

The modified event study methodology is as follows. First we estimate the standardized residual for each stock on the event day (day 0)

$$(3.10) \quad E_{i0} = e_{i0}/\hat{h}_{i0}^{1/2} \sim N(0,1)$$

where $\hat{h}_{i0} = a_{i1} + c_{i1}V_{i0}$. The standardized return residuals are normally distributed in the absence of abnormal performance (see Section 2.A). For an equally weighted portfolio with N stocks, we can compute the local time test statistic for the mean excess return on the portfolio as

$$(3.11) \quad A_0 = \Sigma_{i=1}^{N} E_{i0}/N^{1/2} \sim N(0,1)$$

C. Stock Splits

Stock splits have always intrigued financial economists. For instance, why would stock prices become much more volatile subsequent to the ex-day? One conjecture is offered by Black (1986) who suggests that stock splits might trigger more noise trading which in turn increases stock price volatility. Lamoureux and Poon (1987) suspect that there may be more noise traders when a stock splits for a number of reasons. This seems to be consistent with their findings of an increase in the number of shareholders when a stock splits. Noise traders may well prefer low-priced stocks to high-price stocks, given they are non-information traders and hence more likely "small" individual investors. Also, it is reasonable to argue that the number of transactions per day increases in the context of the tax option model, giving rise to an increase in noise trading; the same suggestion is offered by Black (1986).

From the conjecture that there is an increase in noise trading and noise traders, we can further posit there must be more noise in the price for two reasons. First, an increase in noise trading and noise traders will simply put more noise in the price. Second, the proportional increase in transactions costs will also induce more noise in the observed daily closing prices (see Brennan and Copeland (1988b)). If there is more noise in the price, we should detect a structural shift in eq. (3.3) after a stock splits. Specifically, there should be an increase in the intercept term and/or a decline in the slope coefficient. Further, the conditional distribution of the adjusted residuals might also be affected.

3. Data and Methodology

A. Data

A sample of stock splits is selected from the period 1980-1985, from both the NYSE and the American Stock Exchange

(AMEX). (The original sample is drawn from Lamoureux and Poon (1987)). The split factor must be at least 2.5 (for 1). The stocks must be actively traded. There should be no other splits during the estimation period. The stocks should not have option listed on any exchanges because option listing is likely to affect time deformation (see Chapter V). Daily returns, adjusted for dividends and splits, are taken from the 1987 version of the Center for Research of Security Prices (CRSP) Database. The CRSP equally weighted index is used as the market return. Daily trading volume data are obtained from the S&P's Daily Stock Price (ISL) Book, for the period beginning approximately 6 quarters before the announcement day and ending 6 quarters after the ex-split day. The final sample consists of 21 stocks. Appendix 1 provides a summary of the sample. There are 21 NYSE and 6 AMEX stocks. Both the announcement dates and ex-split dates are obtained from the CRSP database. The former dates are cross-checked with Wall Street Journal Index while the latter dates are cross-checked with the ISL book.

B. Methodology

The model (eq. (3.1)-(3.3)) is estimated by the maximum likelihood estimation technique used in Lamoureux and Lastrapes (1988). The estimation periods for both the pre-split era and post-split era are 300 days where the event period (i.e., the period excluded from the estimation period) is from 30 days prior to the announcement day to 30 days after the ex-day. A typical event study (eq. (3.4)- (3.9)) is conducted on both the announcement and the ex-day. For the announcement day, the OLS market model parameters estimated from the pre-split period are used. On the other hand, for the ex-split day, the parameters obtained from the post-split period are employed. The modified event study (eq. (3.10)-(3.11)) is also applied. Similarly, for the announcement day, the estimates of a_{i1} and c_{i1} from the pre-split period are used to estimate h_{it} whereas for the ex-day, the estimates obtained from the post-split period are used. The inferences drawn from the two event studies are then compared.

In order to focus on the impact of stock split on the stochastic behavior of price, we examine the total daily variance rather than the error variance only. That is, the total variance of daily stock returns is assumed to be conditional upon volume. In order to detect any structural shift as a result of stock splits, a dummy variable D_1 is employed for both the intercept term and the slope coefficient in eq. (3.3). We have

$$(3.12) \qquad h_{it} = a_{i1} + D_1 a_{i2} + c_{i1} V_{it} + D_1 c_{i2} V_{it}$$

where D_1 = 1 in the post-split period;

= 0 in the pre-split period.

Hence a_{i2} and $c_{i2}V_{it}$ respectively represent the marginal changes in the intercept term and the conditional variance due to stock splits. Particularly, we can have the following hypotheses to test whether stock splits induce a structural shift,

H_{01}: $a_{i2} = 0$; and

H_{02}: $c_{i2} = 0$

Notice that these two hypotheses are not mutually exclusive; acceptance of either one might shed light on the conjecture.

4. Empirical Results

A. Raw Return, OLS Market Model, and Volume

As shown in Appendix 1, there is no major clustering in the announcement dates and the ex-dates. (There are 2 announcement days in March 1983, 3 ex-days in June 1980, and 2 ex-days in June 1983.) Most of the splits are 3 for 1. There are 15 NYSE and 6 AMEX stocks.

Table 1 reports the daily average trading volume, closing prices and market values, and the test statistics (formulated by Kiefer and Salmon (1983)) for normality of raw returns for each stock in both pre-split and post-split periods. S is a statistic for skewness while K is for kurtosis and both are distributed χ^2 with 1 d.f. The omnibus test for normality, S+K statistic is distributed χ^2 with 2 d.f. At a 5% level of significance, the null hypothesis of normality is rejected for all companies in the pre-split era, and only 2 companies cannot be rejected in the post-split era. These results are consistent with other evidence which shows that daily return data are not normal (cf. Lamoureux and Lastrapes (1988)). The daily average trading volumes are roughly 245 and 756 hundred shares respectively in the pre- and post-split period. However the post-period split-adjusted volume is about 240 hundred shares. With only two exceptions (company 4 and 21), daily raw volume surges in the post-split period. The average closing price on the announcement day is $73 and the mean market value on that day is $823 million. On the ex-split day, the average closing price drops to $27 (most splits are 3 for 1). The market value increases to $872 million.

Empirical properties of the estimated OLS market model are shown in Table 2. All Companies except 18 have significant $\hat{\beta}$ with an average of 1.1630 in the pre-split period (Panel A). All the residuals except 9's depart from normality. In the post-split period (Panel B), there is a decline in $\bar{\alpha}$. Sixteen out of 21 cases show a drop (the mean drops from 0.0012 to -0.0003). This drop is similar to Lamoureux and Poon's (1987) findings; they also show that the drop is consistent with the tax option model. All $\hat{\beta}$ are significant with an average of 1.4967. This increase in the market model beta seems to be consistent with Lamoureux and Poon (1987) and Brennan and Copeland's (1988a) documentation of a permanent increase in beta after a stock splits. Out of the 21 cases, only 3 do not show an increase in beta. Once again, almost all the residuals exhibit leptokurtosis. In order to test the equality of the error variances in the two periods, the Levene's W 10 test is performed due to the presence of non-normality (see Lamoureux and Poon (1987)). Thirteen stocks have positive significant LW(10) statistics at 5% significance level and only 2 have negative significant LW(10). The average of the signed LW(10) statistic is 11.27 (median 9.08), indicating an increase in the error variance when stocks split.

B. The Time Deformation Market Model

Table 3 contains the empirical results of the estimation of the local time market model.[8] In the pre-split period (Panel A), the estimates of β are similar to those of the OLS market model although the former seems to have slightly smaller value (the mean is 0.9448 compared to 1.1630). All

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[8] Raw trading volume is employed to estimate the local time market model for both pre-split and post-split periods. Since stock returns are market adjusted (the market model is used), one might argue that volume should also be market adjusted. Though not reported, the local time market model is also estimated with the market (NYSE composite) volume as another independent variable in the variance equation (3.3). The coefficients of the market volume are generally insignificant. Therefore, only the results with raw volume are reported in Table 3.

the estimates of a_1 are significant and positive while 15 c_1 are significant and positive. This evidence is very supportive of Lamoureux and Lastrapes (1988). The conditional distribution of the standardized residuals is convincing. The null hypothesis of normality cannot be rejected in 12 stocks compared to only 1 in the OLS model. Moreover, the degree of non-normality in the other 9 stocks is greatly reduced.

Stock splits similarly increase $\hat{\beta}$ in the local time market model (with a mean of 1.3669) in the post-split period. On average, a_1 increases while c_1 drops (c_1 is in fact insignificant in company 19). These changes give the first evidence that stock splits might lead to a poorer fit of the model; an agenda which will be further explored in Part D. The null hypothesis of normality cannot be rejected in 10 cases compared to 2 in the OLS market model. However, the degree of leptokurtosis is actually increased in 2 stocks (companies 4 and 17).

C. The Event Study

(i) With the OLS Market Model

On the announcement day, the portfolio's excess return is as expected: significant, and approximately 1.5% (Table 4, Panel A). The cumulative average excess return (CAR) for day -1 to +1 is 2.4% and significant, indicating the positive announcement effect. The CAR for other subperiods are insignificant. However, the average excess return (AR) for some other days (e.g., day -14 and +19) are also significant but no explanations can be found. For the event study on the ex-day, the post-split market model is used to account for both the increase in beta and error variance. Surprisingly, the excess return on the ex-day (Panel B) is roughly 0.46% but not significant. This is inconsistent with other studies (e.g., Lamoureux and Poon (1987)), probably because of the relatively small sample size. All the CARs for the subperiods are insignificant.

(ii) With the Local Time Market Model

Table 5 documents the results of the event study with the use of the local time market model. The excess return on the announcement day of about 1.7% (Panel A) is still significant. Similar to the typical event study, the ARs are significant for some other days. Note that the t-statistic on a particular day may be negative even though the AR on that day is positive and vice versa (e.g., day -28 and 11). It is because the t-statistic is calculated from standardized residuals. Moreover, the CAR is relatively greater than those in (i). In fact the CAR for day -30 to +30 is significant. One possible explanation for this discrepancy is that $\hat{\beta}$ is usually smaller in the local time market model than in the OLS market model. The results on the ex-day are also very similar to those in the typical event study. The excess return on the ex-day is about 0.5% but insignificant. However, there are also some other days with significant ARs (e.g., day -13 and -3).

The general inferences from both event studies are surprisingly similar. This evidence tends to support the robustness of a typical event study in spite of the violations of the Gauss-Markov assumptions in the OLS market model (cf. Brown and Warner (1985)).

D. The Impact of Stock Splits on the Stochastic Behavior of Stock Returns

Table 6 represents an attempt to demonstrate the hypothesized structural change in the local time market model due to stock splits. Split-adjusted volume is used in estimation of the model. First of all, the value of the likelihood ratio test statistic (LRS) indicates that the unrestricted model fits the data better than the restricted model (with zero a_{i2} and zero c_{i2}). Sixteen Out of 21 stocks have a significant LRS value. The split's impact on the c_{i1} is very small. Only 4 c_{i2} show a significant decline whereas 2 exhibit a significant increase. The most salient evidence for a structural shift comes from the sharp increase in a_i. There are only 2 negative a_{i2} and both are insignificant. On the other hand, 11 a_{i2} are positive and significant. Therefore, the empirical results seem to accept H_{02} but not H_{01} (see Section 4.B). That is, on average, stock splits tend to increase the intercept term but do not affect the slope coefficient in the variance equation even though volume is split-adjusted and there is an increase in price volatility.

In short, the results given by Table 6 tend to suggest that stock splits induce an increase in the intercept term which might be related to the unconditional variance of the price although we cannot distinguish between the different sources (transactions costs and noise trading) of the increase.

5. Conclusions and Research Extensions

Two major conclusions emerge from Chapter III. First, although daily stock returns are heteroskedastic, standard event studies which use the OLS market model seem to be robust. An event study which employs a more sophisticated local time market model yields very similar inferences. Second, the additional volatility due to stock splits is not a result of a faster economic clock nor a more responsive (or sensitive) economic clock. Empirical studies which examine or utilize the price volatility-volume relationship should not neglect the impact of stock splits.

There are at least three directions for future research. Obviously, the first area for future research is to expand the sample size. Second, why is the estimate of β consistently smaller in the local time market model? The

OLS estimate is still unbiased in the presence of heteroskedasticity. Last, empirical results in Table 6 are obtained from examining the total variance. It will be interesting to check the impact of stock splits on the error variance.

CHAPTER IV

THE IMPACT OF OPTION LISTING ON THE UNDERLYING STOCK'S RETURN BEHAVIOR AND TRADING VOLUME

1. Introduction

Since the introduction of organized option trading in 1973, financial economists have been interested in examining the impact of option listing on the underlying stock. One major concern stems from the conjecture that trading activity might be diverted from the stock market to the options markets, followed by a decline in stock trading volumes and hence an increase in stock price volatility (resulting from decreased liquidity). Early studies conducted by Nathan (1974) and the CBOE (1976) do not find evidence that option listing has a negative effect on the underlying stocks. Conversely, a number of studies find that option introduction tends to reduce stock price volatility. Examples are Hayes and Tennenbaum (1979), Trennepohl and Dukes (1980), Klemkosky and Manes (1980), Whiteside, Dukes, and Dunne (1983), and Bansal, Pruitt, and Wei (1989). Specifically, Bansal, Pruitt, and Wei, among others, show that it is the idiosyncratic risk (the error variance in the market model) rather than the market risk (β in the market model) which is reduced by option trading. Furthermore, Ma and Rao (1987) contend that, because of the hedging behavior by uninformed traders and the speculative behavior of informed traders, more volatile stocks will be stabilized by option trading while less volatile stocks will be destabilized.

When the underlying stock's trading volume is concerned, empirical evidence generally shows a positive impact, for instance, Hayes and Tennenbaum (1979), Whiteside, Dukes, and Dunne (1983), and Bansal, Pruitt, and Wei (1989).

Besides the empirical distributions of stock returns and volume, there is yet another important issue associated with option initiation. Essentially, empirical evidence (Epps (1975,1977), Hanna (1978), and Smirlock and Starks (1985)) has documented an asymmetric price change-volume relationship in the sense that the relationship is stronger for positive price changes than for negative price changes. Costly short selling is one major explanation for the existence of the asymmetric relationship. Since option trading (on the underlying stock) reduces the costs of short selling, the proposition that option trading is capable of attenuating the asymmetric relationship becomes an important empirical question (see Karpoff (1987)).

This chapter will serve two purposes. First, the properties of the empirical distributions of stock returns and volume before and after option introduction will be compared. Second, option listing's impact on the structure of price change-volume relationship will be investigated. The implication might be profound for any empirical studies which deal with this relationship if option trading can actually alter its structure.

2. The Asymmetric Price Change-Volume Relationship

A. Theory and Evidence

There are primarily two hypotheses for the existence of an asymmetric price change-volume relationship. Epps (1975) is among the first to address this issue. In Epps' model, all investors can be dichotomized into two groups - the bulls who have an optimistic expectation of a security's future values and the bears who on the other hand have a pessimistic expectation. Epps further assumes investors exhibit "reinforcing-interpreting behavior." In essence, an investor's interpretation of a small piece of new information about the security depends on whether he/she is a bull or a bear in the first place. For a small piece of positive news, the bulls would favorably revise their expectations whereas the bears would not revise theirs. Subsequently, the bulls' demand curve is shifted upward, causing an increase in transaction volume for any given positive price change. On the contrary, for a small piece of bad news, the bears would revise their expectations downward, but the bulls would disregard it. Hence the bears' demand curve becomes flatter, giving rise to a smaller transaction volume for a given negative price change than for the same magnitude of a positive price change.

With transaction data on 20 NYSE bonds, Epps (1975) finds evidence for the asymmetric price change-volume relationship. Similar results are obtained from 20 NYSE stocks for both transaction and daily data in Epps (1977). Later, Hanna's (1978) study on 26 NYSE bonds' transaction data also supports Epps' model. Smirlock and Starks (1985) conduct a more extensive study in terms of the sample size. In selecting their final sample of 131 NYSE stocks, Smirlock and Starks apply two criteria. First, a firm must have an earnings announcement during their estimation period. Second, the firm must also have listed options. Then they test Epps' model with transaction data on the earnings announcement day and on a randomly chosen day with no information arrival. Empirical evidence supports the asymmetric relationship for the earnings announcement day but not for the day with no information. However, their results are subject to possible biases because option listing might be capable of attenuating the asymmetry (see below).

There are other models which also predict the asymmetric relationship without relying on Epps' "reinforcing-interpreting behavior." For instance, Jennings, Starks, and Fellingham (1981) modify Copeland's (1976) sequential information arrival model by including a margin requirement on short selling of a stock. There are three types of investors in their model: (1) uninformed investors; (2) informed investors who are optimistic; and (3) pessimistic investors. Since short positions are now more costly than long positions, an investor's quantity demanded for a security with a short position will be smaller than with a long position for a given price change. They then demonstrate that transaction volume is greater for positive price changes than for negative price changes because price declines when a pessimistic investor sells and rises when an optimistic investor buys the security.

Karpoff (1988), on the other hand, takes a somewhat different approach to look at the price change per se-volume relationship. He posits that, due to the absence of documentation of a price change per se-volume relationship in the futures markets, costly short selling should be important in modelling the relationship. It is because investors face symmetric transaction costs for taking a long or a short position in the futures markets. In Karpoff's model, investor's reaction (to reduce their demand) to bad news is restricted by costly short selling. Hence, the responsiveness of transaction supply to negative information that reduces sellers' demand drops, resulting in a decline of the variance of transaction supply to that of transaction demand. This leads to a positive correlation between price changes and volume. His model is supported indirectly when Karpoff could not find a relationship between price changes per se and transaction volume in the futures markets (with 12 commodities). Therefore, Karpoff's model indirectly supports the proposition that costly short selling is important in explaining the observed asymmetric relationship.

B. Implications

We have discussed two hypotheses for the existence of an asymmetric price change-volume relationship - the "reinforcing-interpreting behavior" and costly short selling. Notice that these two propositions are not mutually exclusive. Nonetheless, option introduction might have different implications for the two propositions. Option trading would practically reduce the costs of taking a short position in the underlying stock. If costly short selling is at least as important as the "reinforcing-interpreting behavior" for the existence of the asymmetry, then it is possible for option trading to attenuate (but not eliminate) the asymmetry. Of course, we presume option trading would not alter investors' "reinforcing-interpreting behavior." Nonetheless, we do not preclude the probability that the bulls or the bears can trade in the options markets. Furthermore, there might exist a new group of investors (neither bulls nor bears) who will now trade in the options markets (and perhaps also in the stock market) when option trading is viable. Therefore, Smirlock and Starks (1985) sample selection criteria might bias their results. And this might explain why they could not find the asymmetry on a day with no information arrival.

How option trading might affect the asymmetric price change-volume relationship is likely a complex question. Investors who trade in the options markets can also trade in the stock market to maintain the put-call parity or some hedge positions (see below). Further, since the stock market specialists can observe (near) real time trading activities in the options markets, they can adjust the bid/ask quotes even though there is no trading in the stock itself (see Chapter V).

Moreover, according to Karpoff (1988), the price change per se-volume relationship exists in the stock market because of the differential costs on taking short and long positions. Then, option trading might weaken the relationship.

In sum, option introduction is likely to alter the structure of the price change-volume relationship in the stock market. The main objective of Chapter IV is to examine any structural shift in the relationship.

3. Data and Methodology

A. Data

During the period 1980-1985, the CBOE has initially listed options on 60 stocks (both NYSE and AMEX).[9] This serves as the initial sample for this chapter. Seven firms do not have volume data available from the ISL books. Twenty six firms have one or more stock splits during the estimation period (see below). These firms are precluded as it is shown in Chapter III that stock splits are likely to induce a structural shift to the price variability-volume relationship. Further, 6 firms have extremely large quarterly dividend payments (more than 8% annual yield). Again, these firms are not included because Lakonishok and Vermaelen (1986) detect unusually high volumes around the ex-dividend days. This tax-induced trading volume might potentially bias any results (as pointed out by Lamoureux and Lastrapes (1988)). The final sample consists of 29 firms. Appendix 2 provides a list of the firms and their options listing dates. All the firms except Amdahl were listed on the NYSE. Stock and market returns are obtained from the 1987 CRSP data base. Stock volume and NYSE composite volume

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[9] Before 1979, the CBOE commonly listed the call options of a stock first and then later listed its puts. From 1979, the CBOE simultaneously listed both calls and puts on the same day. In order to avoid any differential impacts of listing of calls and of puts, this chapter begins in 1980.

(used as a proxy from the market volume) data are taken from the ISL books. The estimated periods are 250 trading days before (pre-option listing period) and 250 days after option listing (post-option listing period).

B. Methodology

The first part of this empirical study will examine the empirical distributions of returns and volume before and after option introduction. The impact of option listing on the structure of the price change-volume relationship will be the focus of the second part.

The effect of option listing on stock return behavior will be investigated by comparing the market model before and after option listing. Several studies, e.g., Bansal, Pruitt, and Wei (1989) have shown that option trading reduces the idiosyncratic risk. Since it is well documented that stock returns do not follow a normal distribution, Levene's W statistic is employed to test for the equality between error variance before and after option trading.

The next step is to compare average daily volumes. Many previous studies find an increase in trading volume as a result of option listing. However, most of them do not correct for stock splits and/or the overall market movement (there are 26 out of 60 firms have splits in the initial sample). Therefore, in addition to comparing raw trading volumes, the market adjusted volume (the ratio of daily stock volume to daily NYSE composite volume) is also examined.

Although empirical evidence for the asymmetric price change-volume relationship is well documented in transaction data, the relationship has not been tested extensively in daily data. The asymmetric relationship which will be tested is as follows:

$$(4.1) \qquad |e_{it}| = a_{i1} + a_{i2}D_1 + b_{i1}VA_{it} + b_{i2}D_1VA_{it} + \varepsilon_{it}$$

where $D_1 = 1$ when $e_{it} \leq 0$;

$= 0$ otherwise.

e_{it} is stock i's return residual obtained from the market model on day t and VA_{it} is the market adjusted volume (the ratio of daily stock volume to daily NYSE composite volume). The dummy variable D_1 captures the asymmetry as it reflects the potential reduction in the coefficient of volume (b_{i1}) when the price change is negative. The testable hypothesis for the existence of the asymmetric price change-volume is

$$H_0: b_{i2} = 0$$

$$H_1: b_{i2} < 0$$

Acceptance of H_1 (as against H_0) gives support to the existence of the asymmetric relationship. OLS will be applied to estimate eq. (4.1) separately for each firm.

Unfortunately, OLS will not be efficient due to the clustering of the listing dates (see Appendix 2). Contemporaneous correlation among stocks' returns is highly possible when clustering occurs. Further, stocks might have similar characteristics for their options to be listed by the CBOE. No contemporaneous correlation is allowed when OLS is applied separately to each firm, however. A more efficient estimation technique such as the seemingly unrelated regression estimation (SURE) which allows for contemporaneous correlation is warranted. Thus, SURE is employed to estimate the system of 29 eq. (4.1) (there are 29 firms in the sample).[10] If costly short selling is a key to the existence of the asymmetry and since option trading could reduce the costs, the asymmetry might be attenuated by option listing. Therefore, we might expect to see $|b_{i2}(\text{pre})| > |b_{i2}(\text{post})|$.

Another testable hypothesis is that the correlation between price changes per se and volume might be weakened upon the introduction of option trading. This can be tested as follows:

$$(4.2) \qquad |e_{it}| = A_{i1} + A_{i2}D_2 + B_{i1}VA_{it} + B_{i2}D_2VA_{it} + \varepsilon_{it}$$

where $D_2 = 1$ in the post-listing period;

$= 0$ otherwise.

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[10] For a description of the SURE procedure, see Judge, Hill, Griffiths, Lütkepohl, and Lee (1982), Ch. 11.

and the testable proposition is

$$H_0: B_{12} \geq 0$$

Again, both OLS and SURE are used to estimate eq. (4.2). Acceptance of H_1 would lend support to the hypothesis that option trading weakens the price change per se-volume relationship.

4. Empirical Results

A. Stock Return Behavior and Trading Volume

It is evident from Appendix 2 that the CBOE tended to list more than one stock's options on a particular day. For example, on June 2, 1980, 7 firms in the sample were listed. The mean closing stock price on the option listing day is $34 and the mean market value on that day is $923 million.

Table 7 summarizes the impact of the introduction of listed option trading on the market model. The average $\hat{\beta}$ is 1.3241 in the pre-listing period compared to 1.3222 in the post-listing period. Moreover, 15 $\hat{\beta}$ show an increase while 14 experience a decline. Thus, it appears that option listing, on average, has only small effect on the market risk. On the other hand, the idiosyncratic risk tends to be reduced. The average signed LW(10) statistic, which is designed to test the equality between error variances under the presence of non-normality -1.752 (median -0.668). When it is not signed, the average is 5.045 which is significant at 5% level. Twenty of the LW(10) statistics are negative (7 significant); 9 are positive (5 significant). In sum, empirical evidence, which is consistent with Bansal, Pruitt, and Wei (1989) and others, suggests that option initiation tends to reduce, though not overwhelmingly, the idiosyncratic risk but leave the market risk unaffected.

Table 8, Panel A presents the changes of raw trading volumes. There are 18 increases (14 significant) and 11 drops (5 significant) in the mean daily volumes. The portfolio has a mean of about 880,000 shares traded daily in the pre-listing period and about 962,000 shares in the post-listing period. The t-statistic for testing the difference in means is 1.60, providing mild support for a positive impact of raw daily volume by option introduction. When the raw volume is adjusted by the market (NYSE composite) volume (the market adjusted volume is a ratio of the stock volume to the market volume), the picture is somewhat different (the results are not reported). Seventeen firms show a drop while 12 experience an increase in the market adjusted volume. Also, the portfolio exhibits a slight decline in the market adjusted volume. This is different from other studies, e.g., Bansal, Pruitt, and Wei (1989).

B. The Asymmetric Price Change-Volume Relationship

OLS is employed to estimate eq. (4.1) separately for each firm and the results for the pre-listing period are reported in Table 9, Panel A. The results are encouraging because 22 firms have negative $\hat{b}_2$ (10 significant) whereas only 7 have positive $\hat{b}_2$ (1 significant). $\hat{b}_2$, representing the drop in $\hat{b}_1$ due to negative price changes, has a mean of -0.0299. The mean of $\hat{b}_1$ which is the coefficient of volume for positive price changes, is 0.0707. In other words, the mean coefficient of volume for negative price changes $\hat{b}_3$ (= $\hat{b}_2$ + $\hat{b}_1$) is 0.0408, or only 57.7% (0.0408/0.0707) of that to positive price changes. This is supportive of the existence of the asymmetric relationship. The change in the intercept term $\hat{a}_2$ due to negative price changes seems to be insignificant; 22 firms have positive $\hat{a}_2$ (5 significant) and 9 have negative $\hat{a}_2$ (1 significant).

Table 9, Panel B contains the results with the use of SURE. Consistent with the results in Panel A, the evidence in Panel B suggests the existence of the asymmetry in the pre-listing period. There are 21 negative $\hat{b}_2$ (10 significant) and 8 positive $\hat{b}_2$ (1 significant). The average of $\hat{b}_1$ is 0.0674 and of $\hat{b}_2$ is -0.0227. The ratio $\hat{b}_3/\hat{b}_1$ is 66.3%. For $\hat{a}_2$, 21 are positive (5 significant) and 8 are negative (1 significant). More importantly, the F statistic for testing the hypothesis

$$a_{12} = b_{12} = 0$$

is 2.3745, which is significant at 5% level. In order to delineate the joint hypothesis, the "single" hypothesis $a_{12} = 0$ is tested and the F statistic is merely 0.7304, not significant at any meaningful level. Therefore, the evidence confirms the asymmetric stock price change-volume relationship in daily data in the pre-option listing period.

The effect of option introduction on the asymmetry is presented in Table 10. Panel A summarizes the results with the use of OLS. The number of negative $\hat{b}_2$ drops from 22 in the pre-listing period to 17 (7 significant). The mean of $\hat{b}_1$ is 0.0670 and of $\hat{b}_2$ is -0.0100. That is, $\hat{b}_3$ increases from 0.0408 to 0.0570 (0.0670 - 0.0100). The ratio $\hat{b}_3/\hat{b}_1$ rises from 57.7% to 85.1%. Table 10, Panel B reports the results from using SURE. Similar to the case of OLS, there are 18 negative $\hat{b}_2$ (7 significant) and 11 positive $\hat{b}_2$ (1 significant). The mean of $\hat{b}_1$ is 0.0653 and of $\hat{b}_2$ is -0.0103. The ratio $\hat{b}_3/\hat{b}_1$ increases from 66.8% (pre-option) to 84.2% (post-option). However, the F statistic for testing the hypothesis $a_{12} = b_{12} = 0$ is 1.884 which is still significant at 5% level. Again, the F statistic for testing the hypothesis $a_{12} = 0$ is 0.7922, not significant at any meaningful level. The evidence gives mild support for the proposition that option listing attenuates but does not eliminate the asymmetry.

Obviously, the issue of how option trading may affect the asymmetric relationship merits further discussion. It is more complicated than it appears. Recall there are two non-competitive theories for the existence of the asymmetry - the "reinforcing-interpreting behavior" assumption and the short selling constraints. If these two factors are equally important in producing the asymmetry, option trading then might attenuate the asymmetry. However, exactly how option trading affects the asymmetry is itself a complex matter (see Karpoff (1987), footnote 15). The asymmetry would be attenuated if the investors with negative information not only trade in the options markets but also act in the stock market to maintain the put-call parity or to obtain some hedged positions, leading to more stock trading volume than before when there is no option trading. On the contrary, the asymmetry would be even stronger if the investors just act in the options markets. Evidence in Table 10 seems to support these two scenarios. Refer to Panel B, 7 out of the 10 significant and negative $\dot{b}_2$ become insignificant or positive and 3 remain significant (and negative). Four negative $\dot{b}_2$, insignificant before, are significant in the post-listing period. In spite of these mixed results, the average of $\dot{b}_2$ does increase from -0.0277 to -0.0103 after option introduction, providing mild support to the proposition that option trading attenuates the asymmetry. Moreover, given that the asymmetry still exists, though weakened, after option introduction, it can also be argued that Epps' "reinforcing-interpreting behavior" theory does have its own place in explaining the asymmetry.

C. The Price Change Per Se-Volume Relationship

Finally, we test whether option introduction weakens the price change per se-volume relationship. Table 11, Panel A gives the results from using OLS. There are 14 negative B_2 (5 significant) and 15 positive B_2 (6 significant). The mean of B_2 is 0.0034. Therefore, the proposition is not well supported. Results from using SURE to estimate eq. (4.2) are reported in Table 11, Panel B. Although the F statistic for testing the hypothesis

$$A_{i2} = B_{i2} = 0$$

is 3.3664 which is significant. The proposition is not well supported since the numbers of negative $\hat{B}_2$ (16 with 5 significant) and positive $\hat{B}_2$ (13 with 6 significant) are very much even. The average of $\hat{B}_1$ is 0.0588 and of $\hat{B}_2$ is 0.0031. Karpoff (1988) claims that price change per se and volume are correlated because of the asymmetry. In this chapter, price change and volume are market adjusted, therefore the impact of option listing on this link might not be as Karpoff would predict.

5. Conclusions and Areas for Future Research

This Chapter examines the impact of option trading on the underlying stock's return behavior and trading volume and on the structure of the price change-volume relationship. Empirical findings for the first part are consistent with other previous studies. The unsystematic risk is reduced while raw trading volume is increased by option introduction. However, when volume is adjusted for the market movement, there is a slight decline. One possible explanation is that there is no stock-splitting firms in our sample whereas other studies do not exclude these firms.

In the context of the structure of the price change-volume relationship, weak evidence is found to support a structural shift due to option trading. The asymmetry is attenuated but the price change per se-volume relationship does not seem to be weakened by option trading. That is, Karpoff's (1988) speculation that the price change per se-volume link is due to the asymmetry seems to be rejected. Option trading is capable of affecting the structure of the asymmetric relationship because the costs of taking a short position in the stock is reduced when option trading is viable. The implications are immediate. Any empirical work that deals with the price change-volume relationship while neglecting the impact of option listing is bound to be biased.

There are at least two areas for future research. First, the asymmetry does not exist for all the firms in the sample. There might be some underlying characteristics which are common to those stocks exhibiting the asymmetry.[11] It will be interesting to know what these characteristics are. Further, option listing seems to have different impacts on different stocks. It will be meaningful to find out what contributes to these differences. Second, this chapter only examines the relationship in the stock market. But if information flows to both the stock and the options markets, one should not be surprised to find out there is a relationship between stock price changes and the trading volume in both markets. Chapter V is directed along this line of research.

[11] The asymmetry is found to be unrelated to the market risk, the idiosyncratic risk, firm size, and trading volume.

CHAPTER V

AN EMPIRICAL EXAMINATION OF THE PRICE VOLATILITY-VOLUME RELATIONSHIP IN RELATED MARKETS: THE CASE OF STOCK AND OPTIONS

1. Introduction

Since the initiation of the public trading in options in 1973, financial economists have been interested in examining the impact of option trading on the underlying common stock. For example, option trading may influence the manner and speed by which stock prices adjust to new information, especially bad news (Patell and Wolfson (1979,1981), Manaster and Rendleman (1982), Bhattacharya (1986), Snelling (1986), and Diamond and Verrecchia (1987)). Options markets are likely to be more attractive than stock markets to informed traders because the former offers higher leverage, lower transactions costs, less stringent margin requirements, and no uptick rule of short selling.

To date, no empirical work has established the relationship between stock price variability and the trading volumes in both stock and options markets. Empirical results related to the stock price volatility-volume relationship may be misleading if the impact of option listing is not considered. In the context of a local time market model (Chapter III), the rate of evolution of stock price may well depend on the trading activity in both stock and options markets, not just the former since options are just derivative securities of the underlying stock.

2. Theoretical Background and Empirical Implications

Black (1975) is among the first to suggest that informed traders may prefer to trade in the options markets than in the stock market because the former provides more economic incentives through reduction in transactions costs and trading restrictions (e.g., short selling constraints). Some studies have then been conducted to investigate the inter-relationship between stock and option prices. Manaster and Rendleman (1982) empirically demonstrate that closing option prices contain fundamental information content that is not revealed in stock prices for a period up to 24 hours. Jennings and Starks (1986) document evidence that stock prices of firms with listed options adjust more rapidly to earnings announcements than the prices of nonoption firms.[12] On the other hand, Snelling (1987) shows that the options markets lead the stock market by roughly 15 minutes during a five trading-day period preceding the earnings

[12] Jennings and Starks' (1986) results are subject to bias due to potential selection bias because option firms and nonoption firms might be different in the first place. Therefore, their results may come from the underlying differences between these firms rather than whether the firms have options listed.

announcement. Also, she provides results which suggest that option prices adjust to the earnings announcement at least 45 minutes prior to the public announcement. All these results seem to support the hypothesis that option prices contain information not reflected in contemporaneous stock prices and hence the possibility of arbitrage. However, Bhattacharya (1987), by examining the option transaction data, contends that the information (therefore the anticipation of stock prices by option prices) seems insufficient to overcome the bid/ask and search costs for intra-day holding periods. Anthony (1988) takes a different approach to examine the inter-relationship between stock and options by investigating trading volume. With the use of causality tests, he shows that in 12 out of 25 firms in his sample call volume leads stock volume by one day. His empirical findings seems to be consistent with previous price-based results.

This chapter takes yet another approach to study the inter-relationship between stock and options. Stock market specialists (both NYSE and AMEX) can observe contemporaneous transactions in the options markets and NYSE specialists can even take hedging positions in the options of the stock in which they make the market. The specialists can reasonably adjust the stock's bid-ask quotes from the trading activity in the options markets even though there is no trading in the stock itself. In other words, the adverse selection problem faced by specialists might be mitigated by option trading.[13] The existence of the price variability-volume relationship in the stock market arises mainly because of the notion that information is impounded in the prices through trading. That is, trading volume could be employed as a proxy for information arrival (see Chapter III). Given that informed traders are more likely to trade in the options markets and that stock and options are not perfect substitutes for one another (as a result of transactions costs), it is logical to conjecture the existence of the cross-market price variability-volume relationship. This relationship will have profound implications on studies of market microstructure because option trading is capable of altering the microstructure of the stock market. The major objective of Chapter V is to provide support for the existence of the price variability-volume relationship in these related markets.

[13] The adverse selection problems arise because of the possibility that there may be traders with superior information which the specialists do not have. Part of the bid-ask spread therefore stems from the specialists protecting themselves from the informed traders. For a further exposition of the adverse selection problems faced by the specialists in the market microstructure literature, see Bagehot (1971) and Glosten and Milgrom (1985).

3. Data and Experimental Design

A. Data

The sample used in Chapter IV serves as the initial sample for this chapter. The final sample consists of 13 NYSE stocks that have options listed on the CBOE between 1982 and 1984. Transaction option data for individual stocks are obtained from the Berkeley Options Data Base. Daily stock return data are taken from the 1987 CRSP database while volume data are collected from the S&P's ISL Book.

B. Experimental Design

Re-consider the local time market model in Chapter III:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it} \tag{3.1}$$

$$\epsilon_{it} | V_{it} \sim N(0, h_{it}) \tag{3.2}$$

$$h_{it} = a_{i1} + c_{i1} VA_{it} \tag{3.3}$$

where R_{it} is stock i's return on day t and R_{mt} is the market return. h_{it} is the conditional variance of the error term and VA_{it} is the contemporaneous market adjusted stock volume. If option trading alters how information is revealed in the stock prices, we would expect a structural shift in the variance equation (3.3). A likelihood ratio test will be performed to test this hypothesis.

Contemporaneous market adjusted stock volume is used as a proxy for information arrival in the local time market model. With the presence of option trading, the information arrival rate is not just proxied by stock volume, but by the volume in both the stock and options markets. In other words, we could estimate the following variance equation,

$$(4.1) \qquad h_{it} = a_{i1} + c_{i1}VA_{it} + c_{i2}O_{it}$$

where O_{it} is the total daily option volume (calls + puts). We also examine whether the disturbance term approaches normality more closely, given a more adequate measure of the economic clock. That is, stock returns would become even less time deformed when option trading is viable. Furthermore, given that option volume is treated as another proxy for information arrival, we would anticipate c_{i2} to be positive. In other words, the portion of the total variance of stock returns which is attributable to economic time increases with an increase in option trading activities.

Since options are derivative securities whose value depends on the underlying stock, we could reformulate eq. (4.1) as

$$(4.2) \qquad h_{it} = a_{i1} + c_{i1}AV_{it}$$

where AV_{it} represents the aggregate contemporaneous market adjusted trading volume in the stock market, or the sum of stock volume and option volume. Of course, calls (and puts) and stock volume cannot simply be lumped together because they are not in compatible units. Both calls and puts have to be transformed into the equivalent stock shares. Two commonly procedures employed to obtain the equivalent stock shares are: (1) from the delta, or hedge ratio ($\partial C/\partial S$ where C is the call (or put) price and S is the stock price); and (2) from the elasticity ($(\partial C/\partial S) x (S/C)$). Obviously, both methods involve the computation of the delta which represents how much the option value will change for a small change in the underlying stock price, ceteris paribus.

Black and Scholes (1973) originally derive a closed-form solution for the valuation of European calls. They show that, given continuous trading, it is possible to form a risk-free hedge portfolio with only two securities - the underlying stock and a call. Moreover, the delta also measures the position in the option that will give almost the same "action" (in dollars) as a position in the stock. For example, if the delta is 0.5, then 2 options will give the "equivalent" action as 1 share of stock. That is, the equivalent stock shares can be obtained by multiplying the delta by the numbers of calls (or puts). Alternatively, we can obtain the equivalent stock shares by multiplying the elasticity by the number of options. The advantage of using the elasticity is that when the option is deep-in-the-money or deep-out-of-the-money, the percentage change of option value to stock value might be a better indication of the position in the stock that will give the equivalent action as a position in the stock than the delta alone.

Black and Scholes' option pricing equations can be used to compute the deltas for European calls and puts only. For American calls with dividends, the Roll (1977)-Whaley (1980) analytic valuation formulas will be employed. For American puts with dividends, Blomeyer's (1986) analytic approximation will be used. Historical stock price volatility is utilized in all cases.

Last, we will examine the empirical implications from Anthony's (1988) study. If option volume really leads stock volume by one day, we would anticipate the following variance equation holds in the local time market model:

$$h_{it} = a_{i1} + c_{i1}O_{i,t-1} \tag{4.2}$$

where $O_{i,t-1}$ is the one-day lagged option volume. In words, we expect the conditional variance of stock returns is positively related to the lagged option volume. The implications might be profound if this equation holds because it implies that we can at least ex-post predict tomorrow's stock price volatility by observing today's option volume.

This prediction is of course not inconsistent with the idea of ARCH where the conditional variance is related to the square of lagged residuals.

4. Empirical Results

Appendix 3 provides a list of the companies studied in this essay. There are 7 firms listed on the CBOE in 1982 and 3 firms respectively in 1983 and 1984. For each firm, the numbers of observations are the same for both the pre-option listing period and the post-option listing period. The average number of observations is 287 trading days.

A. Empirical Properties of Calls and Puts

The statistical properties of option volume is presented in Table 12. The average daily number of calls traded is 452 whereas only 120 puts on average are traded daily. That is, calls are more heavily traded than puts. The Ljung-Box (1978) Q-statistic is computed to test the overall autocorrelation for the option volume. A maximum of lag length 20 is used. With the exception for the puts of Englehard (no. 4) and Loral (no. 6), all the call and put volumes exhibit significant autocorrelation. This piece of evidence suggests that option volume might be a good candidate in explaining the conditional stock return variance in the local time market model (cf. Lamoureux and Lastrapes' (1988) evidence on stock volume).[14]

B. The Impact of Option Listing on the Local Time Market Model with Contemporaneous Stock Volume

The estimation results of the time deformation market model (with contemporaneous stock volume in the variance equation) prior to option introduction are summarized in Table 13, Panel A. The sample has an average of -0.001 in α and of 1.377 in β. All the intercept terms, a_1 (or the unconditional variance) in the variance equation (3.1) are significant, with a mean of 175.685. c_1 is significant except for company 5 and the average is 5.742. However, only 4 firms exhibit normality in the adjusted residuals. The mean S+K statistic (which is designed to test the normality assumption, see Chapter III) is 12.13 (median 9.13).

In the post-option listing period (Table 13, Panel B), The mean α remains at -0.001 while β drops slightly to 1.286. All a_1 and c_1 are significant, with an average of 147.008 and 5.176 respectively. Although the mean S+K statistic increases to 15.32 (median 12.10), there are actually 6 cases (2 more than in the pre-listing period) of normality in adjusted residuals. LRS is the likelihood ratio test

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[14] All the firms in the sample exhibit significant autocorrelation in their stock volume. The Q-statistic (though not reported) for lag length 20 is significant for each firm.

statistic for testing the hypothesis that there is no structural shift in the variance equation by option trading.[15] Out of 13 firms 8 have a significant LRS. These 8 firms have a mean of 133.695 in a_1 and of 3.824 in c_1, compared with 171.740 and 5.066 respectively in the pre-listing period. More careful examination shows that 2 firms have an increase in a_1 and only 3 firms have a rise in c_1.

In short, the results support a structural shift in the relationship between stock price variability and stock volume due to option initiation. Further, the evidence also seems to suggest that contemporaneous market adjusted stock volume explains less of the conditional variance after option introduction, providing a hint that option volume might be important in explaining the conditional variance. Therefore, any empirical research that studies the stock price variability-volume should consider the potential impact by option trading.

C. The Time Deformation Market Model with Contemporaneous Stock Volume and Option Volume

Table 14 reports the estimation results when both contemporaneous market adjusted stock volume and option volume (calls + puts) are present in the variance equation,

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[15] The restrictions are a_{11}(pre-option listing period) = a_{11}(post-option listing period) and c_{11}(pre-listing period) = c_{11}(post-listing period).

i.e., both are treated as proxies for the rate of information arrival. α and β have an average of -0.001 and 1.194 respectively. The mean of a_1 is 119.470. All c_1 (the coefficient of stock volume) are significant. Nonetheless, its mean declines to 4.426 (from 5.176 when option volume is not used). This change in c_1 deserves a more detailed discussion. With the exception of company 1 and 12, the sample firms experience a reduction of c_1 when option volume is incorporated in the variance equation. The implication is that the relationship between stock price variability and stock volume might be over-stated when option volume is ignored.

Option volume is significant in explaining the conditional variance. There are 10 positive (7 significant) and 3 negative (2 significant) c_2; the mean is 0.315. Recall company 1 and 12 show an increase in c_1. It is these two firms which have a negative and significant c_2. The difference in the signs of c_2 is interesting. It is because, unlike stock volume, option volume has different impact on the conditional variance. Furthermore, recall that there are 8 firms showing a structural shift in the variance equation. It appears that for 5 of them, this may be attributed to a significant c_2.

If the use of stock volume and option volume is a better proxy for information arrival than stock volume alone, we would expect the adjusted residuals to be less time deformed.

The S+K statistic seems to give mild support this conjecture. There are also 6 cases (the same firms when only stock volume is used) of normality exhibited in the adjusted residuals. The mean S+K drops from 15.32 (median 12.10) to 13.35 (median 6.29). More importantly, for those 7 firms which do not show normality when only stock volume is used, all their S+K statistics but one are reduced when both stock and option volumes are employed.

In sum, empirical findings are supportive of the proposition that option volume is important in explaining the conditional variance. That is, option volume could be used as a proxy for information arrival. This is consistent with the notion (see Section 2) that informed traders may prefer to trade in the options markets and that the specialists in the stock market can react to the option trading activity by adjusting the bid-ask quotes.

D. The Time Deformation Market Model with Contemporaneous Aggregate Stock Volume

Table 15 provides the estimation results when the aggregate market adjusted stock volume is used in the variance equation. Notice that company 2, 3 and 5 are not presented because it would take too much CPU time to process all their option transactions data. In Panel A the hedge ratio is used to compute the equivalent stock shares. The means of α and β are respectively -0.002 and 1.313. a_1 is significant in all cases except company 7 with an average of 181.587. The coefficient of the aggregate market adjusted stock volume, c_1 has a mean of 5.681 and is significant in all cases. The S+K statistic has a mean of 18.40 compared to 18.19 from the same 10 firms when only market adjusted stock volume is employed. Though not reported, the values of the log-likelihood functions when the aggregate market adjusted stock volume is used are generally algebraically larger than those when only market adjusted stock volume is used. That is, the aggregate stock volume (with the use of the hedge ratio) gives a better fit than stock volume alone. It therefore seems to suggest that the aggregate stock volume is a better proxy for economic time.

Panel B of Table 15 presents the results when the elasticity is used to compute the equivalent stock shares. The averages of α and β are -0.001 and 1.334 respectively. All companies except number 13 have significant a_1 and the mean is 277.025. The average of c_1 is 1.300 and only company 11 has an insignificant c_1. However, when the S+K statistics are compared, it is apparent that the equivalent stock shares obtained from using the elasticity is a poorer indicative than when the hedge ratio is used. The mean of the S+K statistics is 25.26. More critically, all of them are significant at 5% compared to 4 insignificant cases in Panel A. Moreover, the values of the log-likelihood functions are almost always algebraically less than those when only stock volume is employed.

The findings in Table 15 suggest that when we use the hedge ratio to compute the equivalent stock shares and then sum them with the stock volume, this aggregate stock volume is a better proxy for information arrival than stock volume itself. Again, this is consistent with the notion that information will be revealed in both the stock and the options markets.

E. The Time Deformation Market Model with Lagged Option Volume

If option volume leads stock volume by one day as shown by Anthony (1988), whether lagged option volume is able to explain the conditional stock return variance becomes a very interesting question. The estimation results when only (one-day) lagged option volume (calls + puts) is included in the variance equation in the local time market model are contained in Table 16. The averages of α and β are respectively -0.001 and 1.426. The intercept term, a_1 is significant for all the firms and has a mean of 389.183. Most interesting, c_1, the coefficient of lagged option volume is significant in 7 cases (Anthony finds 12 out of 25 cases where call volume leads stock volume by one day). The mean of c_1 is 0.338. Eleven of them are positive (6 significant) and 2 are negative (1 (company 1) significant). The mean S+K statistic is 54.35 (median 22.96) and only 2 firms exhibit normality in the adjusted residuals compared to a mean of 13.35 and 6 firms exhibiting normality when contemporaneous stock and option volumes are used. Nevertheless, the evidence documented in Table 16 does seem to suggest that lagged option volume could explain the conditional stock return variance. And the findings seem to support Anthony's results.

Option volume's power to explain the stock return variability is best depicted by examining Table 14 and 16 together. Except for company 5 and 11, the conditional variance can be explained (partially) by either contemporaneous or lagged option volume. Recall from Table 13, Panel B that there are 8 cases which show a structural shift in the variance equation by option introduction. All these shifts with the exception of company 11 are induced by either a significant effect of contemporaneous or lagged option volume on the conditional variance.

5. Conclusions and Research Extensions

Empirical findings documented in this essay are clearly supportive of a structural shift on the stock price volatility-volume relationship when option trading is viable. The estimated correlation between price volatility and volume will be generally biased upwards if the impact of option introduction is neglected. Furthermore, the conditional variance is found to be related either to contemporaneous and lagged option volume. These results are consistent with Black's (1975) conjecture that informed traders may prefer to trade in the options markets. Moreover, the findings are in agreement with other empirical studies (e.g., Manaster and Rendleman (1982)) which examine the relationship between stock and option prices. Since contemporaneous option volume can explain the conditional stock return variance, it directly proves the relationship between the stock and options markets. The microstructure of the stock market is somewhat influenced by the existence of option trading. The specialists can now react to possible information trading in the options markets even though there is no trading activity in the stock market.

The ability of lagged option volume to explain the conditional stock return variance does not necessarily imply the possibility of arbitrage. This has not been tested and is beyond the scope of this chapter. Future research can center on this issue. Sample size imposes a limitation to the generalization of our conclusions. This research can be expanded to all the sample firms in Chapter V.

One of the potential reasons why lagged option volume can explain the conditional variance is that the CBOE closes 10 minutes later than the NYSE and therefore the importance of lagged option volume might be attributed by trading in the

CBOE after the NYSE is closed (cf. Anthony (1988)). All these transactions can be discarded in future research to check if the one-day-lagged option volume can still explain the conditional variance.

CHAPTER VI

CONCLUSIONS

The major objective of this dissertation is to examine the price volatility-volume relationship. The dissertation begins with an estimation of the time deformation market model in which stock contemporaneous trading volume is utilized as a proxy for the rate of information arrival (Chapter III). This local time market model is economically appealing because it is capable of explaining the observed heteroskedasticity and leptokurtosis in daily return data. With a sample of firms which have stock splits, it is shown that the inferences drawn from a modified event study which incorporates the local time market model are similar to those drawn from a typical event study which uses the simple OLS market model. In order words, a typical event study which employs daily stock return data and the OLS market model yields robust inferences in spite of the violation of the normality assumption in daily return data (cf. Brown and Warner (1985)).

The time deformation market model is also able to show that the increase in price volatility induced by stock splits is due to a structural shift in the model. It is because the intercept term in the variance equation increases while there is no change in the economic clock. However, there are two sources of the increase in the unconditional variance - increase of transactions costs and more noise trading - and future research can be directed to distinguish between these sources.

Then Chapters IV and V are devoted to analysis of the impact of option introduction on the price volatility-volume relationship. Chapter IV examines how the asymmetric price change-volume relationship is affected by option trading. There are principally two mutually non-exclusive explanations for the existence of the asymmetry: (1) different behavioral assumptions for different groups of investors; and (2) the short selling constraints. Option trading is of course capable of reducing the short selling constraints. Although exactly how option trading can affect the asymmetry is a complex matter, the empirical findings do give mild support to the hypothesis that option trading can attenuate the asymmetric price change-volume relationship. However, option listing seems to have different impacts on different stocks. Future research can focus on what causes the differences. Moreover, if more restrictions are imposed on the two explanations for the existence of the asymmetry are separated, we can then examine which one is more important in explaining the asymmetry.

Last, Chapter V investigates how option trading influences the local time market model. Empirical evidence is supportive of a structural shift in the variance equation.

These findings are consistent with the notion that information flows to both the stock and the options markets when option trading is viable. Further, the shift is related to the degree of significance of option volume in explaining the conditional stock return variance. Also, one-day-lagged option volume is important in explaining the conditional variance. This leads to the question of market efficiency which can be studied in future research. Of course, the important role of lagged option volume can be attributed to the non-synchronity between the CBOE and the NYSE. Future research can also address this issue.

Most extant empirical studies on the stock price volatility-volume relationship are focused on how to exploit this relationship. This dissertation on the other hand investigates how this relationship might be affected by some common events such as stock splits and option listing. Empirical findings are supportive of a structural shift in the relationship by stock splits or option trading. Empirical research that utilizes the price volatility-volume relationship should therefore consider the impact of stock splits and of option listing.

Table 1

Empirical Properties of Stock Return and Volume Data

Panel A: Pre-Split Era

Co.	Raw Return S[a]	K[b]	S+K[c]	Daily Average Volume[d]	Price[e]	Market Value[f]
1.	10.16*	97.75*	107.81*	136.21	$ 74.875	$ 728
2.	199.80*	2145.00*	2344.80*	246.88	38.500	275
3.	9.58*	49.04*	58.628*	83.70	79.750	833
4.	0.77*	11.20*	11.97*	291.86	52.750	844
5.	8.98*	19.11*	28.09*	228.98	74.000	424
6.	4.09*	127.45*	131.54*	21.33	43.875	76
7.	27.42*	152.53*	279.95*	47.45	84.250	34
8.	34.43*	163.58*	198.01*	28.24	68.500	238
9.	0.90	36.89*	37.79*	302.97	59.375	511
10.	62.21*	131.97*	194.18*	48.76	68.000	140
11.	46.66*	346.39*	393.05*	53.02	96.000	1822
12.	56.91*	831.02*	887.93*	186.64	77.500	855
13.	0.95	26.23*	27.18*	226.68	48.875	385
14.	20.35*	54.21*	74.56*	62.92	113.000	666
15.	38.36*	312.00*	350.36*	435.90	82.750	1403
16.	11.45*	27.23*	38.68*	1929.29	117.000	4594
17.	1.32	14.88*	16.20*	167.93	87.500	1135
18.	19.44*	60.02*	79.46*	217.89	38.125	202
19.	0.33	28.74*	29.07*	60.56	60.500	556
20.	12.14*	34.89*	47.03*	242.17	91.750	1290
21.	9.58*	7.88*	17.46*	131.11	83.500	268
Mean	27.42	222.76	254.94	245.26	73.351	823
Median:	11.45	54.21	74.56			

Panel B: Post-Split Era

1.	0.64	8.87*	9.51*	417.61	139.20	$33.000	$ 974
2.	11.53*	54.24*	65.77*	230.66	76.89	11.125	239
3.	2.12	2.93	5.05	197.03	65.68	31.500	988
4.	7.05*	13.95*	21.00*	239.27	79.26	17.250	828
5.	70.04*	514.41*	584.45*	1093.17	437.27	34.250	504
6.	38.08*	80.61*	118.69*	114.60	38.20	16.000	83
7.	10.83*	99.81*	110.64*	33.97	11.32	30.500	37
8.	0.00	72.20*	72.20*	258.68	86.23	24.500	255
9.	12.54*	31.81*	44.35*	520.52	208.21	26.750	528
10.	69.13*	277.34*	296.47*	202.56	67.52	27.250	169
11.	38.86*	313.69*	352.55*	808.15	202.04	27.125	2060
12.	18.94*	26.03*	44.97*	691.95	98.85	12.125	937
13.	6.54*	53.12*	59.66*	1604.12	320.82	12.500	493
14.	1.80	129.68*	131.48*	182.25	72.90	73.500	1083
15.	27.51*	269.77*	297.28*	1373.89	457.96	27.500	1403
16.	7.41*	4.03	11.44*	5204.36	1734.79	35.500	4202
17.	30.02*	28.66*	58.68*	546.00	182.00	27.375	1066
18.	38.03*	60.33*	98.36*	548.19	219.28	12.750	186
19.	0.00	0.33	0.33	289.60	96.53	21.250	586
20.	0.00	7.05*	7.05*	998.06	332.69	35.000	1487
21.	3.51	89.62*	93.13*	332.05	110.68	20.500	197
Mean	18.79	101.83	118.48	756.51	239.92	26.536	872
Median:	10.83	54.24	65.77				

[a]The Kiefer-Salmon (1983) test statistic for testing the skewness of a normal distribution, distributed χ^2 with 1 degree of freedom (d.f.).

[b]The Kiefer-Salmon (1983) test statistic for testing the kurtosis of a normal distribution, distributed χ^2 with 1 d.f.

[c]The ominus Kiefer-Salmon (1983) test statistic for testing the normality of a distribution (=S+K), distributed χ^2 with 2 d.f.

[d]In hundred shares.

[d]The closing price on the announcement day in Panel A and on the ex-split day in Panel B respectively.

[f]The market value (in million dollars) on the announcement day in Panel A and on the ex-split day in Panel B respectively.

*Significant at 5% level.

Table 2

Empirical Properties of the OLS Market Model[*]

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$

Panel A: Pre-Split Era

Co.	$\hat{\alpha}$	$\hat{\beta}$	Residuals S+K[*]
1.	0.0022	0.6624*	166.45*
	(0.21)	(6.04)	
2.	0.0015	1.878*	3662.89*
	(0.79)	(8.52	
3.	0.0015	1.2115*	166.29*
	(1.58)	(11.84)	
4.	0.0016	1.3933*	8.14*
	(0.83)	(6.57)	
5.	0.0017	1.3611*	76.71*
	(1.26)	(8.65)	
6.	0.0022*	1.2145*	112.08*
	(2.05)	(10.94)	
7.	0.0002	1.1146*	193.27*
	(0.13)	(5.19)	
8.	0.0015	1.6985*	387.78*
	(1.24)	(10.93)	
9.	0.0015	2.0152*	5.60
	(0.92)	(11.67)	
10.	0.0014	0.9641*	170.20*
	(1.30)	(7.65)	
11.	0.0026*	0.7102*	482.05*
	(2.28)	(5.64)	
12.	0.0010	1.2489*	1137.77*
	(0.91)	(8.58)	
13.	-0.0006	1.4174*	7.12*
	(-0.56)	(8.58)	
14.	0.0019*	0.7352*	10.66*
	(2.54)	(8.12)	
15.	0.0007	1.1017*	591.31*
	(0.91)	(8.31)	
16.	-0.0005	1.5756*	28.38*
	(-0.54)	(11.76)	
17.	0.0004	0.9522*	17.84*
	(0.47)	(9.20)	
18.	0.0028	0.1804	74.63*
	(1.53)	(0.91)	

19.	0.0007	0.5725*	9.97*
	(0.97)	(6.15)	
20.	0.0019	0.9969*	64.91*
	(1.83)	(8.99)	
21.	0.0000	1.4174*	28.04*
	(0.00)	(10.48)	
Mean	0.0012	1.1630	352.48
Median			76.71

Panel B: Post-Split Era

Co.	$\hat{\alpha}$	$\hat{\beta}$	Residuals S+K[a]	Signed LW(10)[b]
1.	0.0002 (0.21)	1.2762* (6.49)	6.78*	14.80*
2.	-0.0008 (-0.60)	1.1741* (5.35)	80.36*	-6.44*
3.	-0.0012 (-1.12)	1.3327* (9.56)	13.86*	7.03*
4.	0.0006 (0.35)	1.8659* (8.24)	36.86*	1.78
5.	0.0010 (0.52)	1.1552* (4.03)	557.25*	8.89*
6.	0.0030 (1.75)	1.2011* (5.10)	176.04*	25.09*
7.	-0.0015 (-1.07)	1.3873* (5.66)	158.98*	-16.26*
8.	-0.0020 (-1.25)	2.1696* (10.99)	39.92*	15.69*
9.	-0.0022 (-1.29)	1.5635* (6.61)	21.76*	0.36
10.	0.0009 (0.56)	1.6153* (6.17)	452.89*	22.46*
11.	-0.0004 (-0.20)	1.2298* (4.97)	528.72*	24.91*
12.	-0.0018 (-1.17)	1.2625* (6.38)	51.65*	31.26*
13.	0.0000 (0.00)	1.9606* (9.04)	38.92*	0.00
14.	-0.0008 (-0.08)	0.8269* (4.83)	156.26*	14.45*
15.	-0.0006 (-0.05)	1.2951* (6.06)	560.26*	16.98*
16.	-0.0014 (-1.21)	2.2265* (10.49)	3.12	3.24
17.	0.0015 (1.27)	1.8473* (8.87)	23.97*	20.43*
18.	-0.0019 (-0.84)	1.7356* (5.59)	115.58*	9.08*

19.	0.0007	0.9559*	2.80	38.18*
	(0.60)	(5.25)		
20.	0.0019	0.9969*	7.02*	2.48
	(0.21)	(12.00)		
21.	0.0000	1.6628*	88.99*	2.28
	(0.00)	(8.00)		
Mean	-0.0003	1.4967	148.61	11.27
Median			9.08	51.61

t-statistics appear in parentheses.

[a] R_{it} is stock i's return on day t, R_{mt} is the market return and ϵ_{it} is the error term.

[b] See footnotes in Table 1.

[c] The Levene W 10 Statistic designed for testing the equality of error variances in the market model before and after stock split, distributed F(1,598)

*Significant at 5% level.

Table 3

The Time Deformation Market Model[a]

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$
$$\epsilon_{it} | V_{it} \sim N(0, h_{it})$$
$$h_{it} = a_{i1} + c_{i1} V_{it}$$

Panel A: Pre-Split Era

Co.	$\hat{\alpha}$	$\hat{\beta}$	$\hat{a}_1$	$\hat{c}_1$	S+K[b]
1.	0.0004	0.4482*	1.737	2.237*	12.68*
	(0.63)	(6.60)	(0.18)	(9.52)	
2.	-0.0017	1.3432*	64.817	3.496*	31.28*
	(-1.38)	(9.00)	(1.88)	(10.56)	
3.	-0.0012	1.0183*	7.684	2.905*	3.05
	(-1.87)	(9.51)	(0.84)	(9.63)	
4.	-0.0004	1.0985*	13.701	3.503*	0.02
	(-0.27)	(6.31)	(0.26)	(7.58)	
5.	-0.0007	1.2347*	97.581*	2.042*	6.39*
	(-0.07)	(8.47)	(2.25)	(5.83)	
6.	0.0007	0.8293*	41.780*	14.098*	4.11
	(0.83)	(8.14)	(3.59)	(8.00)	
7.	-0.0022	0.8187*	-4.478	17.943*	4.08
	(-1.75)	(5.47)	(-0.49)	(10.72)	
8.	-0.0013	1.2441*	59.017*	13.851*	21.82*
	(-1.22)	(8.43)	(2.35)	(7.33)	
9.	-0.0008	1.9621*	241.859*	1.722*	0.41
	(-0.54)	(12.86)	(2.67)	(3.98)	
10.	-0.0007	0.6208*	22.818*	6.749*	3.29
	(-1.04)	(6.13)	(2.34)	(10.05)	
11.	0.0008	0.4621*	97.209*	5.741*	31.92*
	(0.89)	(6.07)	(5.31)	(8.77)	
12.	-0.0009	0.9463*	79.612*	1.747*	179.05*
	(-0.95)	(9.68)	(4.20)	(9.62)	
13.	-0.0022*	1.1841*	107.528*	1.255*	1.23
	(-2.37)	(8.48)	(4.04)	(4.91)	
14.	0.0003	0.5784*	44.122*	2.239*	5.55
	(0.46)	(7.41)	(4.30)	(6.92)	
15.	-0.0004	0.9129*	49.997*	0.326*	11.90*
	(-0.50)	(9.01)	(4.35)	(7.93)	
16.	-0.0018	1.4991*	2.663	0.144*	0.98
	(-1.93)	(11.88)	(0.07)	(5.75)	
17.	-0.0002	0.8826*	61.171*	1.128*	3.61
	(-0.21)	(9.10)	(3.26)	(5.40)	

18.	-0.0005	0.0762	222.003*	3.817*	73.03*
	(-0.35)	(0.67)	(4.00)	(6.39)	
19.	0.0007	0.4861*	64.996*	1.971*	4.23
	(1.09)	(5.73)	(4.06)	(4.49)	
20.	0.0009	0.9714*	98.192*	0.967*	20.48*
	(0.82)	(7.90)	(2.76)	(5.17)	
21.	-0.0008	1.3038*	70.849*	1.960*	2.19
	(-0.93)	(11.89)	(2.88)	(5.43)	
Mean	-0.0005	0.9448	68.803	4.278	20.06
Median					4.23

Panel B: Post-Split Era

1.	0.0003	1.2091*	247.405*	0.339*	5.44
	(0.24)	(6.05)	(5.26)	(2.50)	
2.	-0.0016	1.0191*	178.207*	1.555*	66.22*
	(-1.33)	(4.84)	(4.18)	(5.05)	
3.	-0.0015	1.2437*	171.451*	0.860*	4.41
	(-1.40)	(8.73)	(4.38)	(3.37)	
4.	0.0000	1.7123*	374.772*	2.529*	53.91*
	(-0.02)	(7.61)	(4.38)	(4.26)	
5.	-0.0021	1.1352*	51.598	0.936*	12.28*
	(-1.64)	(5.95)	(1.06)	(7.92)	
6.	0.0003	1.0537*	81.627*	6.871*	31.37*
	(0.25)	(5.08)	(2.54)	(10.80)	
7.	-0.0009	1.1360*	7.886	15.193*	5.09
	(-1.05)	(5.53)	(0.87)	(10.99)	
8.	-0.0060*	1.6904*	88.140	2.544*	1.85
	(-4.15)	(8.68)	(1.50)	(5.91)	
9.	-0.0003	1.4849*	183.823	1.495*	12.65*
	(-1.78)	(6.94)	(1.92)	(4.97)	
10.	-0.0023	1.3372*	136.241*	3.330*	2.79
	(-1.88)	(7.68)	(3.24)	(6.42)	
11.	-0.0043*	1.3417*	125.719*	1.294*	8.24*
	(-3.06)	(6.61)	(2.34)	(8.61)	
12.	-0.0026	1.1962*	407.091*	0.406*	43.76*
	(-1.63)	(6.50)	(6.69)	(3.49)	
13.	-0.0006	1.6816*	126.812*	0.120*	3.63*
	(-0.57)	(9.70)	(5.14)	(5.11)	
14.	-0.0001	0.8414*	90.049*	1.387*	38.34*
	(-0.14)	(4.65)	(3.93)	(7.08)	
15.	-0.0008	1.4063*	161.662*	0.110*	0.39
	(-0.83)	(7.30)	(5.09)	(3.88)	
16.	-0.0008	2.1061*	16.857	0.063*	1.02
	(-0.83)	(10.93)	(0.59)	(7.27)	
17.	0.0011	1.7801*	308.779*	0.245*	29.23*
	(0.87)	(9.11)	(6.21)	(2.24)	
18.	-0.0032	1.1462*	156.672	2.415*	2.83
	(-1.68)	(3.94)	(1.39)	(5.87)	

19.	0.0005	0.8988*	300.259*	0.231	2.98
	(0.47)	(4.76)	(6.38)	(1.33)	
20.	-0.0000	1.6695*	110.930*	0.291*	1.43
	(-0.00)	(13.21)	(2.49)	(4.55)	
21.	0.0004	1.6164*	187.858*	0.829*	8.47*
	(0.38)	(7.40)	(4.92)	(4.60)	
Mean	-0.0013	1.3669	167.673	1.561	16.02
Median					5.44

Asymptotic t-statistics appear in parentheses.

[a] R_{it} is stock i's return on day t, R_{mt} is the market return and ϵ_{it} is the error term. h_{it} is the conditional variance of the error term while V_{it} is the raw daily trading volume.

[b] See footnotes in Table 1.

*Significant at 5% level.

Table 4

An Event Study Using the OLS Market Model

Panel A: The Split Announcement Day (Day 0)

Day	AR[a]	t-stat.	No. of Stocks	Percent Positive	CAR[b]
-30	0.004554	0.963	21	61.90	0.004554
-29	0.000320	0.068	21	52.90	0.004874
-28	0.004854	1.027	21	47.62	0.009728
-27	0.003462	0.732	21	61.90	0.013190
-26	-0.003068	-0.649	21	38.10	0.001012
-25	-0.001600	-0.338	21	47.62	0.008521
-24	-0.000125	-0.026	21	42.86	0.008397
-23	-0.007321	-1.548	21	38.10	0.001076
-22	-0.002292	-0.485	21	33.33	-0.001216
-21	-0.002040	-0.431	21	47.62	-0.003256
-20	0.004273	0.904	21	47.62	0.001018
-19	0.002165	0.458	21	38.10	0.003182
-18	-0.002126	-0.450	21	52.38	0.001056
-17	-0.001702	-0.360	21	47.62	-0.000646
-16	0.006848	1.448	21	57.14	0.006201
-15	-0.000986	-0.209	21	42.86	0.005215
-14	-0.011475	-2.427*	21	23.81	-0.006259
-13	-0.007811	-1.652	21	42.86	-0.014070
-12	-0.000400	-0.085	21	47.62	-0.014470
-11	0.002418	0.511	21	47.62	-0.012053
-10	-0.002725	-0.576	21	38.10	-0.014778
-9	-0.002902	-0.614	21	38.10	-0.017679
-8	0.004011	0.848	21	47.62	-0.013668
-7	0.004010	0.848	21	47.62	-0.009658
-6	-0.000354	-0.075	21	47.62	-0.010012
-5	0.003549	0.751	21	57.14	-0.006463
-4	0.003885	0.822	21	57.14	-0.002577
-3	0.004731	1.001	21	66.67	0.002154
-2	-0.003823	-0.809	21	28.57	-0.001669
-1	-0.005900	-1.248	21	28.57	-0.007569
0	0.015357	3.248*	21	61.90	0.007788
1	0.009040	1.912	21	61.90	0.016827
2	0.004897	1.036	21	57.14	0.021724
3	0.003590	0.759	21	52.38	0.025314
4	-0.000207	-0.044	21	47.62	0.025107
5	0.001218	0.258	21	42.86	0.026325
6	-0.006350	-1.343	21	38.10	0.019974
7	0.004192	0.887	21	38.10	0.024166
8	-0.001024	-0.217	21	47.62	0.023142

9	-0.000640	-0.135	21	47.62	0.022503
10	-0.004672	-0.988	21	28.57	0.017831
11	0.006403	1.354	21	66.67	0.024234
12	0.000034	0.007	21	57.14	0.024267
13	0.000349	0.074	21	38.10	0.024616
14	-0.002779	-0.588	21	52.38	0.021838
15	-0.007409	-1.567	21	47.62	0.014429
16	-0.000706	-0.149	20	40.00	0.013722
17	0.000729	0.154	20	45.00	0.014451
18	-0.006579	-1.392	20	30.00	0.007872
19	-0.011667	-2.468*	20	20.00	-0.003795
20	-0.012368	-2.616*	20	25.00	-0.016163
21	-0.001122	-0.237	19	36.84	-0.017286
22	0.004643	0.982	19	68.42	-0.012643
23	-0.014069	-2.976*	19	26.32	-0.026712
24	0.005043	1.067	19	47.37	-0.021669
25	-0.012316	-2.605*	19	47.37	-0.033984
26	0.003739	0.791	18	55.56	-0.030245
27	0.014733	3.116*	18	61.11	-0.015513
28	0.003671	0.776	16	56.25	-0.011842
29	-0.005136	-1.086	15	40.00	-0.016978
30	0.000524	0.111	14	35.71	-0.016454

CAR(-30 day to +30 day) = -0.016454 with t-stat. of -0.446.
CAR(-30 day to -1 day) = -0.007569 with t-stat. of -0.292.
CAR(-1 day to +1 day) = 0.018497 with t-stat. of 2.259.
CAR(+1 day to +30 day) = -0.024242 with t-stat. of -0.936.

Panel B: The Ex-Split Day (Day 0)

-30	0.004697	0.866	14	64.29	0.004697
-29	-0.002048	-0.377	15	33.33	0.002649
-28	-0.005759	-1.061	16	50.00	-0.003111
-27	0.003568	0.658	18	61.11	0.000457
-26	-0.000245	-0.045	18	55.56	0.000212
-25	-0.005773	-1.064	19	36.84	-0.005562
-24	0.002537	0.468	19	63.16	-0.003025
-23	0.004785	0.882	19	57.89	0.001760
-22	0.004464	0.823	19	63.16	0.006223
-21	0.004846	0.893	19	52.63	0.011069
-20	0.005347	0.985	20	50.00	0.016416
-19	-0.003329	-0.614	20	30.00	0.013087
-18	0.005927	1.092	20	55.00	0.019014
-17	-0.000269	-0.050	20	55.00	0.018745
-16	0.003257	0.600	20	45.00	0.022002
-15	-0.002193	-0.404	21	42.86	0.019808
-14	-0.004820	-0.888	21	42.86	0.014989
-13	-0.008172	-1.506	21	19.05	0.006817
-12	-0.001830	-0.337	21	47.62	0.004987
-11	-0.004040	-0.745	21	33.33	0.000947
-10	-0.005092	-0.937	21	28.57	-0.004136
-9	-0.003743	-0.690	21	38.10	-0.007878
-8	-0.000846	-0.156	21	42.86	-0.008724
-7	0.000779	0.144	21	61.90	-0.007945
-6	0.002247	0.414	21	57.14	-0.005699
-5	0.001073	0.198	21	47.62	-0.004626
-4	-0.003856	-0.711	21	38.10	-0.008482
-3	0.010437	1.924	21	71.43	0.001955
-2	-0.000885	-0.163	21	42.86	0.001072
-1	0.001708	0.315	21	47.62	0.002778
0	0.004567	0.842	21	61.90	0.007345
1	0.005679	1.047	21	47.62	0.013024
2	0.003288	0.606	21	52.38	0.016312
3	-0.005991	-1.104	21	28.57	0.010322
4	-0.000587	-0.108	21	38.10	0.009734
5	0.008411	1.550	21	66.67	0.018145
6	0.004214	0.777	21	52.38	0.022360
7	-0.005072	-0.935	21	42.86	0.017287
8	-0.002883	-0.531	21	52.38	0.014405
9	-0.010079	-1.858	21	28.57	0.004326
10	0.002184	0.403	21	66.67	0.006510
11	0.005113	0.942	21	52.38	0.011623
12	0.005780	1.065	21	52.38	0.017402
13	-0.006144	-1.132	21	33.33	0.011259
14	-0.000928	-0.171	21	42.86	0.010330
15	0.000735	0.135	21	57.14	0.011065
16	-0.004268	-0.787	21	38.10	0.006797
17	0.002112	0.389	21	57.14	0.008909
18	-0.000427	-0.079	21	47.62	0.008482
19	-0.001698	-0.313	21	47.62	0.006784

20	-0.004589	-0.846	21	38.10	0.002195
21	0.003516	0.648	21	61.90	0.005711
22	0.001459	0.269	21	57.14	0.007171
23	0.001317	0.243	21	57.14	0.008488
24	0.008799	1.622	21	57.14	0.017287
25	0.004046	0.746	21	57.14	0.021332
26	0.003505	0.646	21	61.90	0.024837
27	-0.002341	-0.432	21	33.33	0.022495
28	-0.005989	-1.104	21	42.86	0.016507
29	-0.001523	-0.281	21	47.62	0.014984
30	0.000593	0.109	21	57.14	0.015577

CAR(-30 day to +30 day) = 0.015577 with t-stat. of 0.368.
CAR(-30 day to -1 day) = 0.002778 with t-stat. of 0.093.
CAR(-1 day to +1 day) = 0.008538 with t-stat. of 1.272.
CAR(+1 day to +30 day) = 0.008232 with t-stat. of 0.431.

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[a]The average return residual of the portfolio.
[b]The cumulative return residual of the portfolio.
*Significant at 5% level using a one-tailed test.

Table 5

An Event Study Using the Local Time Market Model

Panel A: The Split Announcement Day (Day 0)

Day	AR[a]	t-stat.	No. of Stocks	Percent Positive	CAR[b]
-30	0.006832	0.510	21	61.90	0.006832
-29	0.002180	0.769	21	57.14	0.009011
-28	0.006932	-0.276	21	52.38	0.015943
-27	0.004502	0.732	21	61.90	0.020445
-26	-0.001761	-0.406	21	42.86	0.018684
-25	0.000406	0.423	21	52.38	0.019090
-24	0.000864	-0.169	21	42.86	0.019954
-23	-0.004901	-0.535	21	38.10	0.015053
-22	0.000404	-0.524	21	38.10	0.015457
-21	0.000621	-0.159	21	52.38	0.016077
-20	0.006835	0.459	21	52.38	0.022912
-19	0.004717	0.804	21	42.86	0.027629
-18	-0.000159	-0.051	21	52.38	0.027470
-17	0.000918	1.231	21	52.38	0.028387
-16	0.009031	1.365	21	57.14	0.037419
-15	0.001175	-0.199	21	52.38	0.038594
-14	-0.009214	-2.326*	21	23.81	0.029380
-13	-0.006269	-0.164	21	42.86	0.023110
-12	0.001796	0.009	21	52.38	0.024906
-11	0.004283	0.217	21	47.62	0.029189
-10	-0.000946	-0.333	21	42.86	0.028243
-9	-0.000914	-0.462	21	42.86	0.027329
-8	0.005445	1.473	21	47.62	0.032774
-7	0.006629	1.763	21	61.90	0.039404
-6	0.002178	0.418	21	52.38	0.041582
-5	0.006175	1.793	21	66.67	0.047756
-4	0.005245	1.659	21	61.90	0.053002
-3	0.007268	1.258	21	66.67	0.060270
-2	-0.001938	-0.815	21	42.86	0.058332
-1	-0.003925	-0.800	21	38.10	0.054407
0	0.016955	3.388*	21	71.43	0.071362
1	0.002175	1.739	21	71.43	0.007354
2	0.000060	0.902	21	71.43	0.073597
3	0.001376	0.809	21	57.14	0.074972
4	0.000195	0.276	21	47.62	0.075167
5	0.000217	0.424	21	47.62	0.075384
6	0.001204	-0.821	21	42.86	0.076588
7	0.000872	0.576	21	52.38	0.077460
8	0.000631	0.298	21	52.38	0.078091

9	0.000834	0.351	21	47.62	0.078926
10	0.000730	-1.306	21	33.33	0.079656
11	-0.000057	1.404	21	66.67	0.079598
12	0.001116	0.668	21	61.90	0.080715
13	0.000128	-0.026	21	38.10	0.080843
14	-0.000887	-0.156	21	57.14	0.079956
15	0.000126	-0.088	21	47.62	0.080082
16	0.000676	0.625	20	50.00	0.080757
17	0.000282	0.732	20	45.00	0.081039
18	-0.000533	-0.630	20	30.00	0.080506
19	-0.000064	-2.063*	20	35.00	0.080442
20	0.000374	1.781	20	30.00	0.080816
21	0.000615	-0.054	19	47.37	0.081431
22	0.000462	1.662	19	68.42	0.081893
23	-0.006969	-1.632	19	31.58	0.081197
24	-0.001054	1.077	19	47.37	0.080143
25	0.001209	-1.212	19	57.89	0.081352
26	0.000588	1.200	18	66.67	0.081939
27	0.001004	2.235*	18	77.78	0.082943
28	0.000607	0.886	16	56.25	0.083551
29	0.000606	-0.863	15	46.67	0.084156
30	0.000844	0.278	14	35.71	0.085000

CAR(-30 day to +30 day) = 0.085000 with t-stat. of 2.020.
CAR(-30 day to -1 day) = 0.054407 with t-stat. of 1.292.
CAR(-1 day to +1 day) = 0.015205 with t-stat. of 2.498.
CAR(+1 day to +30 day) = 0.013638 with t-stat. of 0.969.

Panel B: The Ex-Split Day (Day 0)

-30	0.006052	1.459	14	64.29	0.006052
-29	-0.000638	0.031	15	40.00	0.005413
-28	-0.004614	-1.099	16	50.00	0.000799
-27	0.004343	0.361	18	66.67	0.005142
-26	0.000723	0.165	18	55.56	0.005865
-25	-0.004085	-0.696	19	36.84	0.001781
-24	0.003272	1.060	19	57.89	0.005053
-23	0.006088	1.033	19	63.16	0.011141
-22	0.005393	1.273	19	63.16	0.016533
-21	0.005969	1.242	19	52.63	0.022502
-20	0.005985	0.971	20	55.00	0.028488
-19	-0.002280	-1.369	20	35.00	0.026208
-18	0.006973	1.553	20	65.00	0.033180
-17	0.001138	-0.129	20	55.00	0.034318
-16	0.004252	0.507	20	45.00	0.038570
-15	-0.001131	-0.532	21	47.62	0.037439
-14	-0.003662	-0.774	21	52.38	0.033777
-13	-0.007425	-2.192*	21	14.29	0.026353
-12	-0.000899	-0.553	21	47.62	0.025453
-11	-0.003328	-1.209	21	33.33	0.022125
-10	-0.004463	-1.131	21	28.57	0.017662
-9	-0.003038	-0.440	21	38.10	0.014624
-8	-0.000579	0.374	21	42.86	0.014045
-7	0.002194	0.725	21	61.90	0.016239
-6	0.003038	1.197	21	57.14	0.019277
-5	0.001310	1.452	21	52.38	0.021587
-4	-0.002396	-0.860	21	47.62	0.019191
-3	0.010619	3.577*	21	71.43	0.029810
-2	0.000189	-0.219	21	47.62	0.029998
-1	0.002964	0.287	21	61.90	0.032962
0	0.005423	0.287	21	61.90	0.038385
1	0.006779	0.780	21	47.62	0.045164
2	0.003819	0.859	21	52.38	0.048983
3	-0.005139	-1.349	21	33.33	0.043844
4	0.000510	0.245	21	38.10	0.044354
5	0.008033	1.455	21	66.67	0.052387
6	0.006599	-0.313	21	52.38	0.058987
7	-0.003321	-1.143	21	47.62	0.054284
8	-0.001382	-1.258	21	52.38	0.055666
9	-0.008478	-1.374	21	33.33	0.045806
10	0.003492	0.761	21	66.67	0.049298
11	0.005997	0.510	21	57.14	0.055295
12	0.006727	0.755	21	52.38	0.062022
13	-0.004971	-0.996	21	38.10	0.057051
14	0.000252	0.138	21	42.86	0.057303
15	0.002153	0.433	21	57.14	0.059455
16	-0.003453	-0.941	21	38.10	0.056002
17	0.003334	-0.162	21	52.38	0.059336
18	0.000466	-0.034	21	47.62	0.059802
19	-0.001221	-0.217	21	57.14	0.058581

20	-0.003536	-0.854	21	38.10	0.055045
21	0.004076	0.866	21	61.90	0.059121
22	0.003409	0.538	21	61.90	0.062530
23	0.002419	0.496	21	57.14	0.064949
24	0.010059	1.353	21	57.14	0.075008
25	0.004954	0.946	21	57.14	0.079962
26	0.004632	0.309	21	57.14	0.084596
27	-0.001292	0.120	21	38.10	0.083304
28	-0.004933	-1.049	21	42.86	0.078371
29	-0.000785	-0.064	21	57.14	0.077586
30	0.001695	0.325	21	57.14	0.079280

CAR(-30 day to +30 day) = 0.079280 with t-stat. of 0.815.
CAR(-30 day to -1 day) = 0.032962 with t-stat. of 0.687.
CAR(-1 day to +1 day) = 0.015466 with t-stat. of 0.385.
CAR(+1 day to +30 day) = 0.046318 with t-stat. of 0.206.

*Significant at 5% level using a one-tailed test.
[a]See footnotes in Table 4.
[b]See footnotes in Table 4.

Table 6

The Impact of Stock Splits on Time Deformation[a]

$$h_{it} = a_{i1} + D_1 a_{i2} + c_{i1} V_{it} + D_1 c_{i2} V_{it}$$

where D_1 = 1 in the post-split period;
0 in the pre-split period.

Co.	$\hat{a}_1$	$\hat{a}_2$	$\hat{c}_1$	$\hat{c}_2$	S+K[b]	LRS[c]
1.	-2.669	264.907*	2.577*	-1.274*	19.65*	50.68*
	(-0.40)	(5.30)	(11.51)	(-2.60)		
2.	94.543*	85.615	4.285*	1.108	91.47*	7.12*
	(2.03)	(1.34)	(9.95)	(1.00)		
3.	4.927	190.079*	4.279*	-0.574	1.18	39.10*
	(0.37)	(3.60)	(8.81)	(-0.47)		
4.	-70.712	491.115*	4.291*	5.626*	5.04	63.56*
	(-1.46)	(3.78)	(8.97)	(2.36)		
5.	52.828	19.584	3.144*	-0.635	22.86*	1.74
	(1.24)	(0.29)	(7.23)	(-1.18)		
6.	26.870*	66.505	21.380*	1.026	28.89*	6.38*
	(2.79)	(1.89)	(10.48)	(0.35)		
7.	2.885	12.717	20.097*	29.471*	9.13*	55.28*
	(0.09)	(0.34)	(9.00)	(5.34)		
8.	14.948	82.235	23.281*	-12.638*	5.73	10.49*
	(1.00)	(1.16)	(10.98)	(-4.78)		
9.	164.516	61.848	3.319*	0.945	26.84*	2.39
	(1.58)	(0.41)	(6.29)	(0.95)		
10.	24.504*	157.943*	7.794*	3.156	10.79*	47.68*
	(2.40)	(3.00)	(10.25)	(1.62)		
11.	88.554*	170.683*	6.934*	-2.087*	28.29*	7.60*
	(4.71)	(2.49)	(8.66)	(-2.01)		
12.	30.173	422.788*	2.902*	0.457	117.05*	39.51*
	(1.83)	(5.88)	(12.53)	(0.45)		
13.	120.797*	-20.318	1.652*	-0.659*	15.84*	4.98
	(4.01)	(-0.58)	(6.11)	(-2.24)		
14.	33.277*	85.893*	3.356*	-0.034	35.50*	10.21*
	(4.14)	(3.33)	(7.89)	(-0.05)		
15.	56.337*	146.166*	0.418*	-0.072	7.62*	13.86*
	(4.38)	(3.69)	(7.81)	(-0.62)		
16.	-5.734	30.099	0.220*	0.036	4.52	3.36
	(-0.13)	(0.50)	(6.44)	(0.72)		
17.	80.472*	203.589*	1.488*	0.076	28.54*	29.64*
	(3.61)	(3.37)	(5.59)	(0.15)		
18.	224.043*	-132.679	3.803*	3.200*	45.14*	8.52*
	(4.04)	(-0.98)	(6.47)	(2.43)		

19.	68.545*	206.424*	2.303*	-0.941	7.96*	30.96*
	(4.27)	(3.84)	(5.22)	(-1.22)		
20.	75.993*	122.883	1.489*	-0.288	8.93*	3.38
	(2.17)	(1.50)	(7.05)	(-0.78)		
21.	84.504*	152.345*	3.017*	-0.211	7.65*	11.08*
	(2.59)	(2.76)	(5.60)	(-0.25)		
Mean	55.695	134.401	5.811	1.223	25.17	

Asymptotic t-statistics appear in parentheses.

[a] h_{it} is the daily total variance of returns. V_{it} is the raw daily split-adjusted volume.

[b] See notes in Table 1.

[c] LRS = 2(LF1 - LF2) where LF1 is the value of the optimized log of the unrestricted likelihood function while LF2 is that of the restricted likelihood function. LRS is distributed χ^2 with 2 degree of freedom and critical value 5.99 at 5% level.

*Significant at 5% level.

Table 7

Empirical Properties of the Market Model Before and After Option Listing[a]

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$

Co.	Pre Options Listing $\hat{\alpha}$	Pre Options Listing $\hat{\beta}$	Post Options Listing $\hat{\alpha}$	Post Options Listing $\hat{\beta}$	LW(10) Stat.[b]
1.	-0.0001 (-0.06)	0.3382* (1.35)	0.0011 (0.81)	0.6572* (2.90)	-0.616
2.	0.0004 (0.40)	0.9856* (5.66)	0.0005 (0.67)	0.9062* (5.48)	-4.566*
3.	-0.0012 (-0.55)	2.7689* (10.47)	-0.0008 (-0.40)	2.2907* (10.48)	-7.421*
4.	0.0003 (0.33)	1.5676* (10.47)	0.0001 (0.12)	1.2537* (7.92)	4.750*
5.	0.0001 (0.14)	0.7643* (9.22)	-0.0002 (-0.23)	1.1156* (10.14)	0.287
6.	0.0010 (0.67)	2.1754* (9.21)	-0.0003 (-0.30)	1.7575* (8.61)	-26.766*
7.	0.0004 (0.34)	1.7392* (13.17)	-0.0024 (-1.22)	1.2234* (9.76)	6.568*
8.	-0.0009 (-1.12)	0.6684* (8.37)	-0.0004 (-0.44)	1.1980* (9.57)	6.118*
9.	0.0002 (0.15)	1.5235* (7.89)	0.0001 (0.09)	1.0515* (7.89)	-17.405*
10.	0.0003 (0.28)	0.7941* (3.34)	-0.0003 (-0.24)	0.9019* (9.47)	1.994
11.	-0.0008 (-0.68)	1.3871* (10.68)	-0.0013 (-1.09)	1.3335* (8.70)	-0.668
12.	-0.0015 (-1.08)	1.5146* (9.04)	0.0001 (0.12)	1.3251* (7.51)	-7.014*
13.	0.0019 (1.54)	0.9667* (3.66)	0.0001 (0.11)	1.1786* (8.76)	-8.695*
14.	0.0005 (0.37)	1.0378* (3.88)	-0.0020* (-2.06)	1.0905* (7.02)	-3.395
15.	0.0002 (0.15)	1.3095* (10.96)	-0.0007 (-0.68)	0.9988* (7.65)	-6.826*
16.	0.0018 (1.50)	1.2113* (9.58)	-0.0015 (-1.52)	7.7696* (13.46)	-3.182
17.	0.0009 (0.66)	1.4560* (8.15)	-0.0008 (-0.56)	1.0779* (6.79)	-0.319
18.	0.0003 (0.27)	1.0571* (6.77)	-0.0014 (-1.02)	1.1671* (7.22)	1.207

19.	-0.0042*	1.9773*	-0.0010	2.1589*	-0.216
	(-1.96)	(7.84)	(-0.52)	(7.15)	
20.	0.0008	1.0345*	-0.0003	0.9333*	-1.471
	(0.56)	(5.60)	(-0.20)	(6.13)	
21.	-0.0002	0.8294	0.0004	1.2839*	20.493*
	(-0.22)	(8.80)	(0.26)	(7.02)	
22.	0.0003	0.9832*	-0.0003	1.0336*	-3.663
	(0.23)	(7.44)	(-0.24)	(7.60)	
23.	0.0002	0.8362*	-0.0011	1.1201*	-0.313
	(0.15)	(7.17)	(-1.05)	(8.05)	
24.	-0.0005	1.7711*	-0.0013	1.7371*	-2.240
	(-0.29)	(7.54)	(-0.82)	(9.07)	
25.	-0.0002	1.3732*	-0.0012	1.1100*	0.940
	(-0.11)	(7.71)	(-0.72)	(5.81)	
26.	0.0060	0.7910*	-0.0016	0.9319*	-0.805
	(0.00)	(7.30)	(-1.60)	(7.09)	
27.	-0.0002	2.1408*	-0.0027	1.5217*	5.442*
	(-0.14)	(11.07)	(-1.44)	(7.12)	
28.	-0.0026	1.6228*	-0.0017	1.0412*	-2.704
	(-1.18)	(7.05)	(-0.88)	(4.12)	
29.	-0.0008	1.8552*	-0.0010	3.1780*	-0.270
	(-0.41)	(8.17)	(-0.59)	(11.02)	
Mean	0.0001	1.3241	-0.0008	1.3222	-1.752
Median					-0.668

t-statistics appear in parentheses.
[a]See notes in Table 2.
[b]Distributed F(1,598)
*Significant at 5% level using a one-tailed test.

Table 8

Empirical Distribution of Daily Stock Trading Volume Before and After Option Listing[a]

	Pre Options Listing		Post Options Listing	
Co.	Mean	Standard Deviation	Mean	Standard Deviation
1.	897.97	1157.88	822.09	921.90
2.	1177.77	1334.48	1382.76	1160.34
3.	614.22	570.44	505.73	409.87
4.	2534.65	2387.34	2912.26	1588.40
5.	867.14	517.70	1084.14	615.26
6.	6931.46	3898.65	5885.16	3173.68
7.	385.92	309.06	665.13	927.42
8.	225.79	211.12	270.49	248.37
9.	432.42	288.74	434.57	385.49
10.	1274.33	1648.69	1245.22	1401.10
11.	262.67	425.26	218.94	399.49
12.	936.77	969.64	847.37	988.29
13.	807.94	773.84	786.02	683.23
14.	703.61	774.51	847.98	916.17
15.	465.62	344.94	403.21	297.46
16.	969.86	560.68	903.25	490.61
17.	233.72	217.80	435.90	334.64
18.	287.12	297.35	648.44	649.66
19.	684.25	773.31	529.34	481.92
20.	284.19	297.65	543.53	531.23
21.	415.47	363.78	649.62	539.08
22.	553.32	646.00	637.26	534.00
23.	1224.97	1098.69	2152.85	2152.27
24.	435.13	323.30	725.87	538.51
25.	171.67	224.06	552.05	964.78
26.	318.12	295.05	357.58	338.20
27.	232.36	205.05	423.68	364.00
28.	276.63	274.04	282.28	254.57
29.	913.04	824.44	764.72	868.39

Grand Mean : Pre listing 879.94 Post listing 926.33
Standard Deviation: Pre listing 202.49 Post listing 189.44

[a]Volume is in hundred shares.

Table 9

Test of the Asymmetric Price Change-Volume Relationship in the Pre-Option Listing Period*

$$|e_{it}| = a_{i1} + D_1 a_{i2} + b_{i1} VA_{it} + D_1 b_{it} VA_{it}$$

$$\text{where } D_1 = 1 \text{ when } e_{it} \leq 0; \quad = 0 \text{ otherwise.}$$

Panel A: With the Use of Ordinary Least Squares

	$\hat{a}_1$	$\hat{a}_2$	$\hat{b}_1$	$\hat{b}_2$
1.	9.1551*	2.3066	0.0820*	-0.0133
	(5.66)	(1.00)	(8.40)	(-0.89)
2.	4.1199*	4.9496*	0.0631*	-0.0498*
	(2.95)	(2.55)	(8.04)	(-4.07)
3.	7.1448*	11.0061*	0.1640*	-0.1163*
	(2.68)	(3.04)	(9.20)	(-4.53)
4.	7.5264*	0.8436	0.0064*	-0.0017
	(7.18)	(0.57)	(2.08)	(-0.35)
5.	8.2419*	-1.0367	0.0089	0.0019
	(5.69)	(-0.50)	(1.40)	(0.21)
6.	4.8435*	8.1538*	0.0196*	-0.0126*
	(1.65)	(1.87)	(4.78)	(-1.97)
7.	8.2868*	2.7298	0.0949*	-0.0614*
	(3.87)	(0.98)	(4.61)	(-2.30)
8.	8.3454*	-0.4590	0.0101	0.0207
	(7.91)	(-0.30)	(0.60)	(0.91)
9.	12.3593*	2.3309	0.0808*	-0.0504
	(5.41)	(0.73)	(3.68)	(-1.52)
10.	8.7134*	-0.4728	0.0328*	-0.0005
	(6.58)	(-0.26)	(4.98)	(-0.05)
11.	13.2332*	0.6139	0.0232	-0.0205
	(7.20)	(0.28)	(0.83)	(-0.69)
12.	13.3362*	1.1495	0.0324*	-0.0128
	(7.27)	(0.44)	(2.34)	(-0.62)
13.	8.1618*	2.9352	0.0774*	-0.0786*
	(4.59)	(1.25)	(6.53)	(-3.27)
14.	6.4154*	3.9309*	0.0918*	-0.0399
	(4.69)	(1.83)	(9.31)	(-1.62)
15.	9.9805*	3.9643	0.0451*	-0.0409*
	(5.42)	(1.60)	(3.08)	(-1.97)

16.	6.1764*	0.2983	0.0373*	-0.0058
	(2.31)	(0.08)	(4.15)	(-0.39)
17.	11.9823*	1.1157	0.0988*	-0.0244
	(7.15)	(0.43)	(3.52)	(-0.48)
18.	13.9716*	-1.8903	0.0127	0.0237
	(9.80)	(-0.91)	(0.74)	(0.89)
19.	17.1902*	-9.3923*	0.0945*	0.1117*
	(6.42)	(-2.73)	(3.44)	(3.25)
20.	10.4816*	-0.2952	0.1272*	-0.0395
	(5.56)	(-0.12)	(5.18)	(-1.18)
21.	9.9695*	-1.7970	0.0207*	-0.0070
	(6.86)	(-0.91)	(1.79)	(-0.42)
22.	7.1102*	3.0253	0.0573*	-0.0321*
	(4.51)	(1.32)	(8.24)	(-2.26)
23.	7.8169*	3.9607*	0.0207*	-0.0199*
	(4.52)	(1.75)	(5.02)	(-3.22)
24.	12.3087*	4.9725	0.1232*	-0.0699
	(4.08)	(1.25)	(3.49)	(-1.62)
25.	9.0582*	4.8667*	0.2524*	-0.2428*
	(4.93)	(2.07)	(6.03)	(-4.73)
26.	11.4480*	-1.6472	0.0152	0.0123
	(7.13)	(-0.79)	(0.81)	(0.56)
27.	15.0185*	-0.8318	0.0624	0.0111
	(6.57)	(-0.27)	(1.44)	(0.19)
28.	14.9547*	4.2876	0.1835*	-0.1055*
	(5.65)	(1.06)	(7.65)	(-2.12)
29.	10.7530*	2.4022	0.1123*	-0.0057
	(4.61)	(0.74)	(6.39)	(-0.22)
Mean	9.9346	0.0707	1.7938	-0.0299

Panel B: With the Use of SURE

1.	8.7451*	2.7821	0.0812*	-0.0075
	(5.75)	(1.33)	(9.14)	(-0.55)
2.	4.0339*	4.7708*	0.0633*	-0.0467*
	(2.92)	(2.52)	(8.28)	(-3.92)
3.	8.7170*	9.1222*	0.1481*	-0.0950*
	(3.38)	(2.65)	(8.74)	(-3.89)
4.	7.8988*	0.6965	0.0056*	-0.0028
	(7.86)	(0.50)	(1.91)	(-0.61)
5.	8.1494*	-0.0201	0.0077	0.0001
	(6.17)	(-0.01)	(1.35)	(0.01)
6.	5.3793*	7.0468*	0.0193*	-0.0119*
	(1.92)	(1.70)	(4.96)	(-1.97)
7.	8.4683*	1.6302	0.0949*	-0.0517*
	(4.14)	(0.62)	(5.08)	(-2.04)
8.	8.5683*	-0.2619	-0.0010	0.0300
	(8.77)	(-0.19)	(-0.06)	(1.46)
9.	12.9848*	1.1853	0.0787*	-0.0465
	(5.95)	(0.39)	(3.79)	(-1.48)
10.	8.3614*	0.3026	0.0331*	-0.0018
	(6.64)	(0.18)	(5.34)	(-0.21)
11.	13.5291*	0.1844	0.0149	-0.0078
	(7.68)	(0.09)	(0.56)	(-0.28)
12.	12.8159*	1.5468	0.0352*	-0.0114
	(7.40)	(0.65)	(2.74)	(-0.60)
13.	7.6679*	3.0140	0.0786*	-0.0681*
	(4.47)	(1.35)	(6.98)	(-2.98)
14.	7.1221*	2.5747	0.0872*	-0.0289
	(5.38)	(1.27)	(9.30)	(-1.24)
15.	10.6635*	2.3127	0.0367*	-0.0199
	(6.23)	(1.01)	(2.74)	(-1.04)
16.	7.7201*	-2.6621	0.0312*	0.0081
	(3.24)	(-0.84)	(3.94)	(0.62)
17.	12.1280*	0.3761	0.0925*	0.0001
	(7.48)	(0.15)	(3.45)	(0.01)
18.	13.6925*	-1.7948	0.0208	0.0164
	(10.16)	(-0.94)	(1.30)	(0.67)
19.	17.3268*	-10.0044*	0.0955*	0.1152*
	(6.75)	(-3.09)	(3.69)	(3.56)
20.	10.2884*	0.1592	0.1267*	-0.0406
	(5.55)	(0.07)	(5.29)	(-1.24)
21.	9.4344*	-0.9544	0.0231*	-0.0102
	(6.89)	(-0.52)	(2.15)	(-0.66)
22.	6.9995*	3.1188	0.0551*	-0.0262*
	(4.61)	(1.44)	(8.34)	(-1.95)
23.	7.6360*	4.5632*	0.0210*	-0.0218*
	(4.51)	(2.08)	(5.26)	(-3.63)
24.	12.8299*	5.0100	0.1153*	-0.0682*
	(4.58)	(1.37)	(3.57)	(-1.72)
25.	9.5091*	3.9271*	0.2442*	-0.2236*
	(5.18)	(1.70)	(5.93)	(-4.42)

26.	11.0754*	-1.2081	0.0200	0.0073
	(7.15)	(-0.61)	(1.12)	(0.34)
27.	16.5240*	-2.2372	0.0287	0.0402
	(7.75)	(-0.80)	(0.72)	(0.76)
28.	14.2078*	4.3660	0.1846*	-0.0844*
	(5.46)	(1.11)	(7.88)	(-1.74)
29.	11.3802*	0.7804	0.1122*	-0.0011
	(5.18)	(0.26)	(6.90)	(-0.05)
Mean	10.1330	0.0674	1.3906	-0.0227

Proof of the existence of the asymmetric price change-volume relationship:

The F statistic for testing the hypothesis

$$H_0 : a_2 = b_2 = 0$$

is 2.375 which is significant at 5%, with degree of freedom (58,7134).

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t-statistics appear appear in parentheses.

[a] e_{it} is stock i's return residual obtained from the market model (Table 7). VA_{it} is the market adjusted volume (the ratio of stock volume to the NYSE composite volume).

*Statistically significant at 5% level.

Table 10

Test of the Asymmetric Price Change-Volume Relationship in the Post-Option Listing Period[a]

$$|e_{it}| = a_{i1} + D_1 a_{i2} + b_{i1} VA_{it} + D_1 b_{i2} VA_{it}$$

where $D_1 = 1$ when $e_{it} \leq 0$;
$= 0$ otherwise.

Panel A: With the Use of Ordinary Least Squares

	$\hat{a}_1$	$\hat{a}_2$	$\hat{b}_1$	$\hat{b}_2$
1.	12.6887*	-0.7976	0.0490*	0.0043
	(6.57)	(-0.32)	(2.62)	(0.18)
2.	3.2653*	4.1417*	0.0423*	-0.0360*
	(3.27)	(2.98)	(9.14)	(-4.01)
3.	14.7844*	-9.7877*	0.0509*	0.1247*
	(5.83)	(-2.95)	(2.16)	(4.05)
4.	0.4999	6.4086*	0.0513*	-0.0369*
	(0.26)	(2.78)	(6.81)	(-4.08)
5.	6.2931*	3.5759	0.0210*	-0.0229*
	(3.62)	(1.58)	(2.88)	(-2.32)
6.	4.9254*	1.7394	0.0110*	0.0004
	(2.91)	(0.71)	(4.09)	(0.09)
7.	9.5644*	2.8772	0.0792*	-0.0197
	(4.07)	(0.91)	(6.12)	(-1.29)
8.	8.4387*	0.2645	0.0664*	-0.0329
	(6.60)	(0.15)	(4.07)	(-1.31)
9.	10.4864*	-0.6643	0.0659*	0.0090
	(6.89)	(-0.30)	(2.76)	(0.23)
10.	12.6341*	-2.5876	0.0228*	0.0212
	(7.43)	(-0.99)	(2.32)	(0.87)
11.	11.4577*	1.0744	0.0562*	-0.0493*
	(10.02)	(0.66)	(5.77)	(-2.61)
12.	11.1800*	-0.2142	0.0246*	0.0080
	(8.42)	(-0.12)	(2.10)	(0.54)
13.	4.7082*	1.3984	0.0956*	-0.0296
	(3.79)	(0.87)	(6.79)	(-1.32)
14.	9.8484*	0.5340	0.0327*	-0.0098
	(7.42)	(0.30)	(2.00)	(-0.44)

15.	10.6945*	0.1240	0.0192	-0.0012
	(5.73)	(0.05)	(0.81)	(-0.04)
16.	8.4989*	-0.3963	0.0181*	0.0097
	(4.06)	(-0.15)	(1.70)	(0.68)
17.	10.6607*	0.9325	0.1107*	-0.0301
	(4.88)	(0.32)	(2.96)	(-0.58)
18.	8.6943*	0.1031	0.0819*	0.0107
	(4.68)	(0.04)	(4.15)	(0.45)
19.	13.2107*	-2.9296	0.1567*	0.0965
	(5.73)	(-0.79)	(5.35)	(1.48)
20.	8.2101*	-1.9613	0.1118*	-0.0107
	(4.79)	(-0.83)	(5.36)	(-0.39)
21.	6.7400*	5.4937*	0.0754*	-0.0541*
	(3.44)	(1.91)	(6.86)	(-2.71)
22.	6.8182*	0.3129	0.0481*	-0.0154
	(5.12)	(0.17)	(7.52)	(-1.22)
23.	9.0099*	1.0620	0.0084*	-0.0017
	(7.50)	(0.59)	(4.64)	(-0.50)
24.	18.0039*	-2.8934	0.0178	0.0349
	(6.78)	(-0.77)	(0.69)	(0.94)
25.	15.1942*	-0.8238	0.0208*	-0.0046
	(10.43)	(-0.41)	(1.91)	(-0.24)
26.	6.5418*	-0.0640	0.0705*	0.0048
	(4.23)	(-0.03)	(3.44)	(0.20)
27.	14.9882*	-1.2820	0.1518*	0.0042
	(5.88)	(-0.36)	(3.75)	(0.07)
28.	9.0447*	7.3853*	0.2736*	-0.1915*
	(3.49)	(2.03)	(7.86)	(-3.39)
29.	16.2879*	0.6231	0.1075*	-0.0707*
	(7.06)	(0.21)	(4.26)	(-2.33)
Mean	9.7818	0.0670	0.4706	-0.0100

Panel B: With the Use of SURE

1.	12.7319*	-0.8436	0.0472*	0.0075
	(6.94)	(-0.36)	(2.69)	(0.34)
2.	3.6506*	3.2462*	0.0414*	-0.0318*
	(3.68)	(2.37)	(9.06)	(-3.59)
3.	15.1177*	-9.7548*	0.0490*	0.1205*
	(5.97)	(-2.96)	(2.09)	(3.94)
4.	0.8741	6.0981*	0.0496*	-0.0355*
	(0.47)	(2.71)	(6.75)	(-4.02)
5.	6.9941*	2.8165	0.0177*	-0.0193*
	(4.16)	(1.29)	(2.52)	(-2.03)
6.	5.4105*	1.4241	0.0102*	0.0006
	(3.41)	(0.63)	(4.08)	(0.17)
7.	9.8178*	1.5318	0.0752*	-0.0053
	(4.45)	(0.53)	(6.36)	(-0.38)
8.	8.7544*	0.0387	0.0596*	-0.0267
	(7.09)	(0.02)	(3.82)	(-1.11)
9.	10.5953*	-0.3727	0.0629*	0.0028
	(7.28)	(-0.18)	(2.79)	(0.08)
10.	13.4916*	-2.3359	0.0136	0.0171
	(8.53)	(-0.99)	(1.53)	(0.78)
11.	12.1317*	-0.1148	0.0471*	-0.0328*
	(11.04)	(-0.08)	(5.22)	(-1.87)
12.	10.8619*	0.3139	0.0301*	-0.0019
	(8.55)	(0.19)	(2.71)	(-0.13)
13.	5.4543*	0.4274	0.0879*	-0.0205
	(4.61)	(0.28)	(6.62)	(-0.97)
14.	10.5293*	-0.0908	0.0227	-0.0020
	(8.54)	(-0.06)	(1.52)	(-0.10)
15.	10.8537*	-0.4874	0.0211	-0.0010
	(6.08)	(-0.22)	(0.93)	(-0.04)
16.	8.2140*	0.6093	0.0191*	0.0045
	(4.18)	(0.24)	(1.93)	(0.34)
17.	10.5857*	1.0252	0.1145*	-0.0367
	(5.19)	(0.38)	(3.31)	(-0.77)
18.	7.7564*	1.4677	0.0898*	0.0024
	(4.34)	(0.63)	(4.76)	(0.11)
19.	12.4034*	-0.9602	0.1786*	0.0378
	(5.65)	(-0.28)	(6.50)	(0.62)
20.	8.1073*	-0.9793	0.1126*	-0.0160
	(4.77)	(-0.44)	(5.70)	(-0.62)
21.	6.0384*	6.2744*	0.0772*	-0.0529*
	(3.19)	(2.28)	(7.26)	(-2.77)
22.	7.1713*	-0.1649	0.0469*	-0.0140
	(5.72)	(-0.10)	(7.92)	(-1.21)
23.	8.9773*	1.3785	0.0093	-0.0043
	(7.91)	(0.83)	(0.54)	(-1.39)
24.	18.2180*	-2.8272	0.0178	0.0289
	(7.41)	(-0.82)	(0.76)	(0.85)
25.	15.5962*	-1.3051	0.0166	-0.0008
	(11.13)	(-0.69)	(1.61)	(-0.05)

26.	6.3624*	-0.0730	0.0737*	0.0041
	(4.31)	(-0.04)	(3.80)	(0.18)
27.	14.6865*	-0.7283	0.1445*	0.0199
	(6.10)	(-0.22)	(3.82)	(0.33)
28.	9.5683*	7.6520*	0.2534*	-0.1774*
	(3.79)	(2.18)	(7.55)	(-3.26)
29.	15.9370*	1.3463	0.1050*	-0.0674*
	(7.13)	(0.47)	(4.36)	(-2.32)
Mean	9.8928	0.0653	0.5039	-0.0103

Proof of the proposition that options trading attenuates the asymmetric price change-volume relationship:

The F statistic for testing the hypothesis

$$H_0: a_2 = b_2 = 0$$

is 1.884 (drops from 2.374 in the pre-options listing period); still significant at 5% level.

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t-statistics appear in parentheses.
[a]See notes in Table 9.
*Significant at %5 level.

Table 11

The Impact of Option Listing on the Price Change Per Se-Volume Relationship[a]

$$|e_{it}| = a_{i1} + D_1 a_{i2} + b_{i1} VA_{it} + D_1 b_{it} VA_{it}$$

where D_1 = 1 in the post-listing period;
= 0 otherwise.

Panel A: With the Use of Ordinary Least Squares

	$\hat{a}_1$	$\hat{a}_2$	$\hat{b}_1$	$\hat{b}_2$
1.	10.3497*	1.9483	0.0759*	-0.0240*
	(9.41)	(1.17)	(10.76)	(-1.73)
2.	6.3575*	-1.5814	0.0427*	-0.0098
	(7.79)	(-1.28)	(8.42)	(-1.32)
3.	12.5840*	-3.4311	0.1104*	0.0092
	(7.35)	(-1.35)	(9.07)	(0.43)
4.	7.8900*	-2.4549	0.0061*	0.0192*
	(10.18)	(-1.88)	(2.42)	(4.02)
5.	7.8444*	0.5119	0.0089*	0.0004
	(7.41)	(0.33)	(1.92)	(0.06)
6.	8.1377*	-1.7135	0.0147*	-0.0048
	(4.52)	(-0.70)	(5.62)	(-1.26)
7.	9.4336*	2.3268	0.0658*	-0.0017
	(5.08)	(1.03)	(3.65)	(-0.09)
8.	7.8942*	0.3208	0.0265*	0.0307*
	(9.19)	(0.27)	(2.07)	(1.77)
9.	12.9883*	-2.6124	0.0629*	0.0035
	(9.09)	(-1.37)	(4.24)	(0.13)
10.	8.4118*	3.3192*	0.0328*	-0.0062
	(8.39)	(2.26)	(6.49)	(-0.66)
11.	13.9713*	-2.3940*	0.0047	0.0386*
	(15.25)	(-1.94)	(0.51)	(3.08)
12.	13.8155*	-2.8004*	0.0273*	0.0029
	(12.27)	(-1.84)	(3.06)	(0.23)
13.	8.0582*	-2.4275*	0.0659*	0.0157
	(8.69)	(-1.76)	(7.88)	(0.96)
14.	7.6548*	2.6270*	0.0864*	-0.0604*
	(8.55)	(1.97)	(10.62)	(-4.09)

15.	11.8285*	-0.8173	0.0270*	-0.0086
	(10.07)	(-0.50)	(2.75)	(-0.54)
16.	5.6589*	3.3218	0.0370*	-0.0172*
	(3.67)	(1.51)	(6.03)	(-1.67)
17.	12.4148*	-1.1784	0.0927*	0.0035
	(9.98)	(-0.62)	(4.23)	(0.10)
18.	13.1036*	-4.5841*	0.0227*	0.0673*
	(12.31)	(-2.93)	(1.66)	(3.89)
19.	11.3978*	1.3713	0.1649*	0.0133
	(7.04)	(0.57)	(10.30)	(0.42)
20.	10.1579*	-2.5940	0.1080*	-0.0029
	(8.60)	(-1.50)	(6.86)	(-0.14)
21.	9.1370*	-0.9416	0.0177*	0.0455*
	(7.50)	(-0.55)	(1.73)	(3.53)
22.	7.8468*	-1.2802	0.0501*	-0.0051
	(8.14)	(-0.91)	(9.44)	(-0.62)
23.	9.6650*	-0.2565	0.0128*	-0.0048
	(9.09)	(-0.18)	(4.39)	(-1.44)
24.	15.6079*	0.9704	0.0758*	-0.0410
	(8.33)	(0.36)	(3.84)	(-1.49)
25.	12.5818*	2.1784	0.0911*	-0.0707*
	(10.84)	(1.40)	(3.68)	(-2.68)
26.	10.5408*	-4.1111*	0.0232*	0.0511*
	(11.13)	(-3.04)	(2.46)	(3.58)
27.	14.1314*	0.6328	0.0825*	0.0686
	(8.79)	(0.28)	(2.72)	(1.63)
28.	15.4209*	-2.6620	0.1625*	0.0275
	(8.71)	(-1.00)	(8.23)	(0.76)
29.	12.5059*	3.6932*	0.1078*	-0.0398*
	(7.49)	(1.64)	(8.00)	(-2.00)
Mean	10.5997	-0.5041	0.0588	0.0034

Panel B: With the Use of SURE

1.	10.1689*	1.8807	0.0779*	-0.0227*
	(9.34)	(1.14)	(11.41)	(-1.69)
2.	6.3798*	-1.5770	0.0425*	-0.0098
	(7.87)	(-1.29)	(8.62)	(-1.36)
3.	13.5437*	-2.6887*	0.0303*	0.0020
	(12.28)	(-1.80)	(3.54)	(0.17)
4.	7.9783*	-2.2222*	0.0057*	0.0182*
	(10.22)	(-1.70)	(2.28)	(3.81)
5.	7.8607*	0.5147	0.0088*	0.0004
	(7.66)	(0.35)	(1.98)	(0.06)
6.	8.0117*	-1.4393	0.0149*	-0.0053
	(4.50)	(-0.59)	(5.80)	(-1.41)
7.	9.3404*	2.1813	0.0669*	-0.0008
	(5.12)	(0.98)	(3.82)	(-0.05)
8.	8.130*	0.2824	0.0219*	0.0315*
	(9.65)	(0.24)	(1.78)	(1.89)
9.	12.8855*	-2.3703	0.0642*	-0.0010
	(9.18)	(-1.27)	(4.45)	(-0.04)
10.	8.2529*	3.6128*	0.0341*	-0.0090
	(8.32)	(2.49)	(6.99)	(-0.99)
11.	13.9208*	-2.2217*	0.0055	0.0348*
	(15.25)	(-1.81)	(0.62)	(2.85)
12.	13.5437*	-2.6887*	0.0303*	0.0020
	(12.28)	(-1.80)	(3.54)	(0.17)
13.	8.0401*	-2.4355*	0.0661*	0.0159
	(8.76)	(-1.79)	(8.08)	(0.99)
14.	7.7947*	2.2481*	0.0844*	-0.0542*
	(8.69)	(1.68)	(10.56)	(-3.75)
15.	11.8251*	-0.7885	0.0270*	-0.0090
	(10.33)	(-0.50)	(2.86)	(-0.59)
16.	5.7246*	3.3096	0.0367*	-0.0173*
	(3.92)	(1.59)	(6.42)	(-1.79)
17.	12.1362*	-1.0344	0.0994*	-0.0002
	(9.94)	(-0.55)	(4.69)	(-0.01)
18.	12.8683*	-4.4248*	0.0272*	0.0638*
	(12.09)	(-2.84)	(2.03)	(3.75)
19.	11.4755*	0.9545	0.1637*	0.0214
	(7.16)	(0.40)	(10.47)	(0.70)
20.	10.1610*	-2.7238	0.1079*	-0.0009
	(8.65)	(-1.59)	(6.96)	(-0.04)
21.	8.9903*	-1.0894	0.0192*	0.0464*
	(7.38)	(-0.64)	(1.91)	(3.65)
22.	8.0032*	-1.6438	0.0488*	-0.0021
	(8.46)	(-1.19)	(9.61)	(-0.27)
23.	9.6331*	-0.3330	0.0129*	-0.0046
	(9.21)	(-0.24)	(4.56)	(-1.43)
24.	15.7521*	0.8659	0.0739*	-0.0396
	(8.63)	(0.33)	(3.91)	(-1.50)
25.	12.8181*	1.9406	0.0833*	-0.0629*
	(11.10)	(1.25)	(3.44)	(-2.43)

26.	10.4424*	-3.8984*	0.0246*	0.0480*
	(11.00)	(-2.88)	(2.62)	(3.38)
27.	12.1362*	-1.0344	0.0994*	-0.0002
	(9.94)	(-0.55)	(4.69)	(-0.01)
28.	15.3110*	-1.7662	0.1642*	0.0103
	(8.74)	(-0.67)	(8.60)	(0.29)
29.	12.5192*	3.6837*	0.1076*	-0.0397*
	(7.65)	(1.67)	(8.30)	(-2.08)
Mean	10.5965	-0.4940	0.0588	0.0031

t-statistics appear in parentheses.
[a]See notes in Table 9.
*Significant at 5% level.

Table 12

Empirical Properties of Calls and Puts

	Calls		Puts	
Co.	Average Daily Numbers of Contracts	Q(20)[a]	Average Daily Numbers of Contracts	Q(20)[a]
1.	74.91 (213.93)	70.16	11.64 (38.82)	235.79
2.	1278.57 (2983.25)	39.74	65.92 (96.61)	90.28
3.	2839.74 (2278.62)	254.76	896.61 (529.33)	170.09
4.	116.14 (147.12)	287.58	10.13 (22.96)	23.67
5.	138.79 (316.77)	41.71	37.93 (51.54)	42.24
6.	122.60 (190.02)	40.29	37.81 (122.78)	12.03
7.	153.82 (207.85)	200.13	78.79 (153.83)	266.32
8.	87.24 (123.93)	363.80	24.91 (61.37)	43.77
9.	280.43 (464.01)	107.23	134.09 (232.04)	118.54
10.	358.13 (399.68)	612.94	194.05 (176.41)	328.86
11.	102.10 (364.18)	949.45	30.90 (163.59)	296.42
12.	157.99 (238.94)	437.11	9.76 (17.74)	66.29
13.	164.41 (211.07)	373.30	30.74 (39.00)	254.88
Mean	451.91		120.25	

Standard deviations appear in parentheses.

[a]Q(20) is the Ljung-Box (1978) Q-statistic for testing the overall autocorrelation for the squared residuals. A maximum of lag length 20 is used. Q(20) is distributed $\chi^2(20)$ with critical value of 31.41 at 5% level.

Table 13

The Time Deformation Market Model With Contemporaneous Stock Volume[a]

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$
$$\epsilon_{it} | V_{it} \sim N(0, h_{it})$$
$$h_{it} = a_{i1} + c_{i1} VA_{it}$$

Panel A: Pre-Options Listing Period

Co.	$\hat{\alpha}$	$\hat{\beta}$	$\hat{a}_1$	$\hat{c}_1$	S+K[b]
1.	-0.001	0.487*	124.923*	4.439*	2.40
	(-0.93)	(6.60)	(3.38)	(6.32)	
2.	-0.001	1.019*	90.071*	1.330*	50.26*
	(-0.62)	(8.77)	(5.79)	(9.08)	
3.	0.000	2.071*	60.829	0.723*	0.17
	(0.00)	(10.38)	(0.71)	(4.06)	
4.	-0.002	1.403*	159.021*	5.326*	0.26
	(-1.22)	(7.47)	(2.42)	(4.57)	
5.	-0.001	1.364*	436.111*	0.600	7.70*
	(-0.79)	(11.22)	(8.36)	(0.95)	
6.	0.000	1.341*	217.978*	5.281*	9.70*
	(0.00)	(9.87)	(5.39)	(3.92)	
7.	0.000	1.060*	197.121*	3.320*	9.13*
	(0.00)	(8.21)	(5.21)	(4.48)	
8.	-0.004*	1.844*	116.976*	11.331*	17.55*
	(-2.29)	(12.64)	(2.31)	(5.54)	
9.	0.000	0.750*	67.613*	7.203*	18.21*
	(0.00)	(6.54)	(2.65)	(7.24)	
10.	-0.001	1.694*	266.195*	5.909*	17.86*
	(-0.71)	(10.68)	(2.93)	(3.95)	
11.	-0.003*	1.139*	19.862	18.384*	9.05*
	(-2.74)	(8.06)	(0.59)	(7.81)	
12.	-0.001	2.016*	414.715*	2.523*	14.84*
	(-0.75)	(11.02)	(7.72)	(1.94)	
13.	-0.003*	1.712*	112.485*	8.280*	0.60
	(-1.80)	(8.70)	(2.37)	(7.08)	
Mean	-0.001	1.377	175.685	5.742	12.13
Median					9.13

Panel B: Post-Options Listing Period

Co.	$\hat{\alpha}$	$\hat{\beta}$	$\hat{a}_1$	$\hat{c}_1$	S+K[b]	LRS[c]
1.	0.001	0.698*	235.129*	2.158*	27.35*	11.90*
	(0.49)	(3.90)	(7.87)	(4.41)		
2.	-0.002*	0.803*	-0.799	0.985*	14.14*	75.24*
	(-3.04)	(6.85)	(-0.09)	(9.14)		
3.	-0.001	1.544*	12.815	0.381*	2.26	55.38*
	(-0.55)	(7.13)	(0.44)	(4.56)		
4.	-0.004	0.882*	51.633*	5.727*	12.10*	18.06*
	(-0.41)	(8.38)	(1.69)	(5.73)		
5.	-0.001	1.249*	83.218*	2.952*	0.88	55.30*
	(-0.70)	(8.59)	(2.81)	(4.53)		
6.	-0.001	1.036*	210.450*	4.369*	2.76	1.68
	(-0.90)	(8.82)	(4.90)	(3.54)		
7.	-0.001	0.987*	90.455*	4.782*	5.34	5.22
	(-0.60)	(8.17)	(2.11)	(5.68)		
8.	-0.003*	2.270*	37.956	15.703*	4.95	4.32
	(-2.11)	(10.09)	(0.60)	(6.54)		
9.	0.000	0.743*	50.437*	5.731*	1.98	8.16*
	(0.00)	(6.63)	(2.09)	(6.76)		
10.	-0.001	1.721*	321.068*	3.520*	17.54*	5.86
	(-0.83)	(10.48)	(4.03)	(2.88)		
11.	-0.001	1.086*	356.095*	2.870*	74.04*	69.18*
	(-0.77)	(7.77)	(8.29)	(3.30)		
12.	-0.003*	1.409*	281.029*	9.789*	23.32*	18.54*
	(-1.76)	(8.86)	(4.11)	(4.07)		
13.	-0.002	2.294*	181.613*	8.315*	12.51*	3.76
	(-1.14)	(10.06)	(3.37)	(5.90)		
Mean	-0.001	1.286	147.008	5.176	15.32	
Median					12.10	

Asymptotic t-statistics appear in parentheses.

[a]R_{it} is stock i's return on day t, R_{mt} is the market return and ϵ_{it} is the error term. h_{it} is the conditional variance of the error term while VA_{it} is the daily market adjusted trading volume.

[b]See footnotes in Table 1.

[c]LRS = 2(LF1 - LF2) where LF1 is the value of the optimized log of the unrestricted likelihood function while LF2 is that of the restricted likelihood function. The restrictions are on the variance equation: a_{i1}(pre-option listing) = a_{i1}(post-option listing) and c_{i1}(pre-option listing) = c_{i1}(post-option listing). LRS is distributed χ^2 with 2 degree of freedom and critical value 5.99 at 5% level.

*Significant at 5% level.

Table 14

The Time Deformation Market Model
with Contemporaneous Stock and Options Volumes[a]

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$
$$\epsilon_{it} | V_{it} \sim N(0, h_{it})$$
$$h_{it} = a_{i1} + c_{i1} VA_{it} + c_{i2} O_{it}$$

Co.	$\hat{\alpha}$	$\hat{\beta}$	$\hat{a}_1$	$\hat{c}_1$	$\hat{c}_2$	S+K[b]
1.	0.001	0.740*	249.350*	2.295*	-0.371*	21.41*
	(0.53)	(3.99)	(8.07)	(4.75)	(-2.87)	
2.	-0.001	0.685*	-1.869	0.979*	0.003	10.37*
	(-0.91)	(5.59)	(-0.20)	(6.42)	(0.60)	
3.	0.000	1.481*	-0.185	0.203*	0.029*	3.64
	(0.00)	(7.25)	(-0.05)	(1.92)	(2.24)	
4.	0.000	0.868*	49.851*	2.625*	1.016*	6.29*
	(0.00)	(8.45)	(1.87)	(2.90)	(3.89)	
5.	-0.001	1.235*	76.935*	2.901*	0.062	0.94
	(-0.74)	(8.43)	(2.53)	(4.25)	(0.38)	
6.	-0.002	1.008*	162.252*	3.061*	0.744*	4.12
	(-1.34)	(8.50)	(3.99)	(2.69)	(2.31)	
7.	-0.001	0.962*	40.902*	3.132*	0.786*	2.14
	(-1.02)	(7.75)	(1.12)	(4.36)	(3.21)	
8.	-0.002	1.575*	-1.956	14.876*	0.495	2.24
	(-1.24)	(8.01)	(-0.05)	(7.01)	(0.98)	
9.	0.000	0.736*	37.275*	4.511*	0.201*	1.99
	(0.00)	(6.67)	(4.63)	(1.81)	(1.73)	
10.	-0.002	1.595	225.358*	2.274*	0.373*	20.27*
	(-1.[illegible]3)	(9.60)	(2.99)	(2.30)	(2.92)	
11.	-0.001	1.071*	362.167*	2.970*	-0.131	73.57*
	(-0.74)	(7.59)	(8.38)	(3.10)	(-0.62)	
12.	-0.003*	1.406*	264.055*	11.625*	-0.379*	19.23*
	(-2.28)	(8.91)	(4.12)	(4.96)	(-2.34)	
13.	-0.002	2.159*	81.981	6.085*	1.266*	7.30*
	(-1.20)	(9.32)	(0.91)	(3.36)	(2.57)	
Mean	-0.001	1.194	119.470	4.426	0.315	13.35
Median						6.29

Asymptotic t-statistics appear in parentheses.

[a]R_{it} is stock i's return on day t, R_{mt} is the market return and ϵ_{it} is the error term. h_{it} is the conditional variance of the error term. VA_{it} is the daily market adjusted trading volume. O_{it} is the total option contracts traded (calls + puts).

[b]See footnotes in Table 1.

*Significant at 5% level.

Table 15

The Time Deformation Market Model with Contemporaneous Aggregate Stock Volume[a]

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$
$$\epsilon_{it} | V_{it} \sim N(0, h_{it})$$
$$h_{it} = a_{i1} + c_{i1} AV_{it}$$

Panel A: With the Use of Hedge Ratio to Obtain Equivalent Stock Shares[b]

Co.	$\hat{\alpha}$	$\hat{\beta}$	$\hat{a}_1$	$\hat{c}_1$	S+K[c]
1.	0.001	0.695*	242.574*	1.970*	28.48*
	(0.53)	(3.92)	(7.97)	(4.26)	
4.	0.000	0.878*	46.354*	4.844*	9.06*
	(0.00)	(10.48)	(1.61)	(5.84)	
6.	-0.001	1.019*	192.250*	3.999*	3.55
	(-1.10)	(8.86)	(4.28)	(3.59)	
7.	-0.001	0.983*	65.752	4.328*	2.15
	(-0.78)	(8.07)	(1.60)	(6.09)	
8.	-0.002	1.579*	-0.466	15.395*	2.12
	(-1.43)	(7.87)	(-0.09)	(7.77)	
9.	0.000	0.743*	50.439*	5.731*	1.98
	(0.00)	(6.63)	(2.09)	(6.76)	
10.	-0.002	1.640*	243.709*	3.293*	19.15*
	(-1.05)	(9.91)	(2.91)	(3.31)	
11.	-0.001	1.103*	370.134*	2.215*	80.46*
	(-0.74)	(7.94)	(8.25)	(2.61)	
12.	-0.003	1.416*	128.328*	7.011*	26.28*
	(-1.65)	(8.98)	(4.72)	(3.58)	
13.	-0.002	2.232*	133.444*	8.021*	10.75*
	(-1.19)	(9.75)	(2.24)	(5.85)	
Mean	-0.001	1.313	147.252	5.681	18.40
Median					9.91

Panel B: With the Use of Elasticity to Obtain Equivalent Stock Shares[d]

1.	0.001	0.666*	328.765*	0.575*	37.08*
	(0.77)	(4.14)	(9.37)	(3.65)	
4.	-0.001	0.920*	64.839*	1.412*	8.17*
	(-0.61)	(9.85)	(2.31)	(5.39)	
6.	-0.001	1.007*	261.639*	0.751*	6.95*
	(-1.11)	(8.39)	(6.43)	(2.93)	
7.	-0.001	1.055*	169.888*	0.756*	10.40*
	(-0.80)	(8.00)	(4.23)	(5.20)	
8.	-0.003*	2.158*	168.481*	4.653*	12.23*
	(-1.78)	(11.68)	(2.42)	(5.84)	
9.	0.000	0.795*	123.929*	0.511*	16.36*
	(0.00)	(7.61)	(4.42)	(6.71)	
10.	-0.002	1.744*	477.588*	0.235*	12.92*
	(-0.94)	(10.39)	(7.05)	(2.16)	
11.	0.000	1.124*	446.190*	0.199	111.29*
	(0.00)	(8.19)	(12.12)	(0.84)	
12.	-0.002	1.443*	564.971*	0.661*	24.93*
	(-1.37)	(8.84)	(9.91)	(1.73)	
13.	-0.002	2.436*	163.963	3.242*	12.23*
	(-0.88)	(10.66)	(1.68)	(4.38)	
Mean	-0.001	1.334	277.025	1.300	25.26
Median					12.58

Asymptotic t-statistics appear in parentheses.

[a]R_{it} is stock i's return on day t, R_{mt} is the market return and ϵ_{it} is the error term. h_{it} is the conditional variance of the error term. AV_{it} is the sum of market adjusted stock volume and equivalent stock shares calculated from both calls and puts and is market adjusted.

[b]The equivalent stock shares are obtained by multiplying Δ and O where Δ is the hedge ratio $\partial C/\partial S$ (C is the call or put price while S is the stock price) and O is the number of calls or puts traded.

[c]The equivalent stock shares are obtained by multiplying Ω and O where Ω is the elasticity $(\partial C/\partial S)x(S/C)$ (C is the call or put price while S is the stock price) and O is the number of calls or puts traded.

[c]See footnotes in Table 1.

*Significant at 5% level.

Table 16

The Time Deformation Market Model
with Lagged Options Volume[a]

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$
$$\epsilon_{it} | V_{it} \sim N(0, h_{it})$$
$$h_{it} = a_{i1} + c_{i1} O_{i,t-1}$$

Co.	$\hat{\alpha}$	$\hat{\beta}$	$\hat{a}_1$	$\hat{c}_1$	S+K[b]
1.	0.001	0.673*	451.098*	-0.165*	53.44*
	(1.13)	(4.14)	(14.61)	(-2.19)	
2.	-0.001*	0.933*	71.128*	0.016*	289.81*
	(-1.78)	(7.87)	(16.24)	(3.13)	
3.	0.000	1.777*	121.522*	0.026*	0.01
	(0.00)	(8.01)	(3.56)	(2.35)	
4.	0.000	1.023*	171.758*	0.970*	9.51*
	(0.00)	(10.11)	(7.05)	(4.39)	
5.	0.000	1.379*	299.535*	-0.045	0.35
	(0.00)	(9.07)	(9.39)	(-0.41)	
6.	-0.001	1.085*	371.308*	0.296	10.25*
	(-0.45)	(8.12)	(7.13)	(0.85)	
7.	-0.001	1.223*	412.966*	0.226	65.88*
	(-0.55)	(7.93)	(12.15)	(1.47)	
8.	-0.002	2.274*	621.204*	1.720*	35.15*
	(-0.86)	(10.39)	(7.93)	(2.58)	
9.	0.001	0.896*	272.142*	0.328*	91.78*
	(0.42)	(6.98)	(8.16)	(3.38)	
10.	-0.002	1.788*	542.394*	0.129	11.98*
	(-0.90)	(10.58)	(8.02)	(1.13)	
11.	0.000	1.086*	476.618*	0.005	104.66*
	(0.00)	(7.82)	(16.41)	(0.04)	
12.	-0.002	1.450*	664.104*	0.134	22.96*
	(-1.18)	(8.61)	(11.68)	(0.51)	
13.	-0.001	2.954*	583.602*	0.759*	10.71*
	(-0.84)	(13.48)	(8.15)	(2.59)	
Mean	-0.001	1.426	389.183	0.338	54.35
Median					22.96

Asymptotic t-statistics appear in parentheses.

[a] R_{it} is stock i's return on day t, R_{mt} is the market return and ϵ_{it} is the error term. h_{it} is the conditional variance of the error term. $O_{i,t-1}$ is the total options contracts traded (calls + puts) on day t-1.

[b] See footnotes in Table 1.

*Significant at 5% level.

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Appendix 1

Sample Firms Used in Chapter III

Company	Announcement Date	Ex-Split Date	Split Factor	Exchange
1. American Stores	3-9-83	8-1-83	3.00	NYSE
2. Asamera	8-18-83	9-12-83	3.00	AMEX
3. Cabot	8-8-80	11-5-80	3.00	NYSE
4. Campbell Red Lakes	3-19-81	6-2-81	3.00	NYSE
5. Copper Labs	3-17-83	5-3-83	2.50	NYSE
6. Dreyfus	1-13-81	2-19-81	3.00	NYSE
7. Espey	9-14-83	1-3-84	3.00	AMEX
8. Felmont Oil	2-25-80	6-10-80	3.00	AMEX
9. First Miss.	11-6-80	12-18-80	2.50	NYSE
10. Hazeltine	4-19-83	6-1-83	3.00	NYSE
11. Hudsons	2-8-80	5-27-80	4.00	AMEX
12. Husky Oil	5-1-80	6-2-80	7.00	AMEX
13. KLM	7-24-84	10-25-84	5.00	NYSE
14. Mercantile Stores	2-3-83	6-16-83	2.50	NYSE
15. Morton Thiokol	8-23-84	11-19-84	3.00	NYSE
16. Motorola	2-7-84	6-4-84	3.00	NYSE
17. New York Times	10-20-83	12-22-83	3.00	AMEX
18. Sunshine Mining	2-8-80	3-20-80	2.50	NYSE
19. U. S. Tobacco	10-21-82	1-25-83	3.00	NYSE
20. Waste Management	2-24-81	6-30-81	3.00	NYSE
21. Watkins Johnson	12-27-83	2-6-84	3.00	NYSE

Appendix 2

Sample Firms Used in Chapter IV

Company	Option Listing Date[a]	Stock Price[b]	Market Value[c]
1. Alex and Alex	2-21-84	$20.500	$ 525
2. Allied Stores	12-26-84	49.625	1041
3. Amdahl	6-29-81	36.250	620
4. American General	7-30-85	31.625	2212
5. Bristol Myers	6-2-80	36.750	2409
6. Chrysler	12-26-84	31.750	127
7. Computer Services	8-1-80	25.375	334
8. Corning Glass	6-2-80	50.000	881
9. Englehard	6-28-82	19.000	512
10. Internorth	10-14-85	43.125	1897
11. Evens Products	6-2-80	20.375	251
12. First Chicago	8-29-83	24.375	1003
13. Gen Corp	12-23-85	63.250	1384
14. Grumman	10-14-85	32.500	936
15. Harris	8-8-80	45.000	1369
16. Litton Industries	6-2-80	52.375	1926
17. Loral	6-28-82	34.000	346
18. Medtronic	4-13-82	38.750	608
19. NBI	8-29-83	27.750	276
20. Northrop	4-13-82	48.750	728
21. Northwest Industries	6-2-80	31.625	946
22. Owens Illinois	6-2-80	23.250	664
23. Ralston Purina	6-2-80	11.500	1241
24. Rolm	3-22-82	29.750	512
25. Sabine	6-28-82	33.250	481
26. Tektronix	8-1-80	65.250	1199
27. Tidewater	6-28-82	21.625	359
28. UNC	8-8-80	14.625	154
29. Winnebago	8-29-83	17.000	430
Mean		33.724	923

[a]Options listed on the CBOE.

[b]The closing price of the stock on the option listing date.

[c]The market value of the stock on the option listing date, in million dollars.

Appendix 3

Sample Firms Used in Chapter V

Company	Option Listing Date[a]	Number of Observations[b]
1. Alex and Alex	2-21-84	300
2. Allied Stores	12-26-84	253
3. Chrysler	12-26-84	253
4. Englehard	6-28-82	300
5. First Chicago	8-29-83	275
6. Loral	6-28-82	300
7. Medtronic	4-13-82	300
8. NBI	8-29-83	275
9. Northrop	4-13-82	300
10. Rolm	3-22-82	300
11. Sabine	6-28-82	300
12. Tidewater	6-28-82	300
13. Winnebago	8-29-83	275

[a]Options listed on the CBOE

[b]The numbesr of observations are the same for both the pre-option listing period and the post-listing period.

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